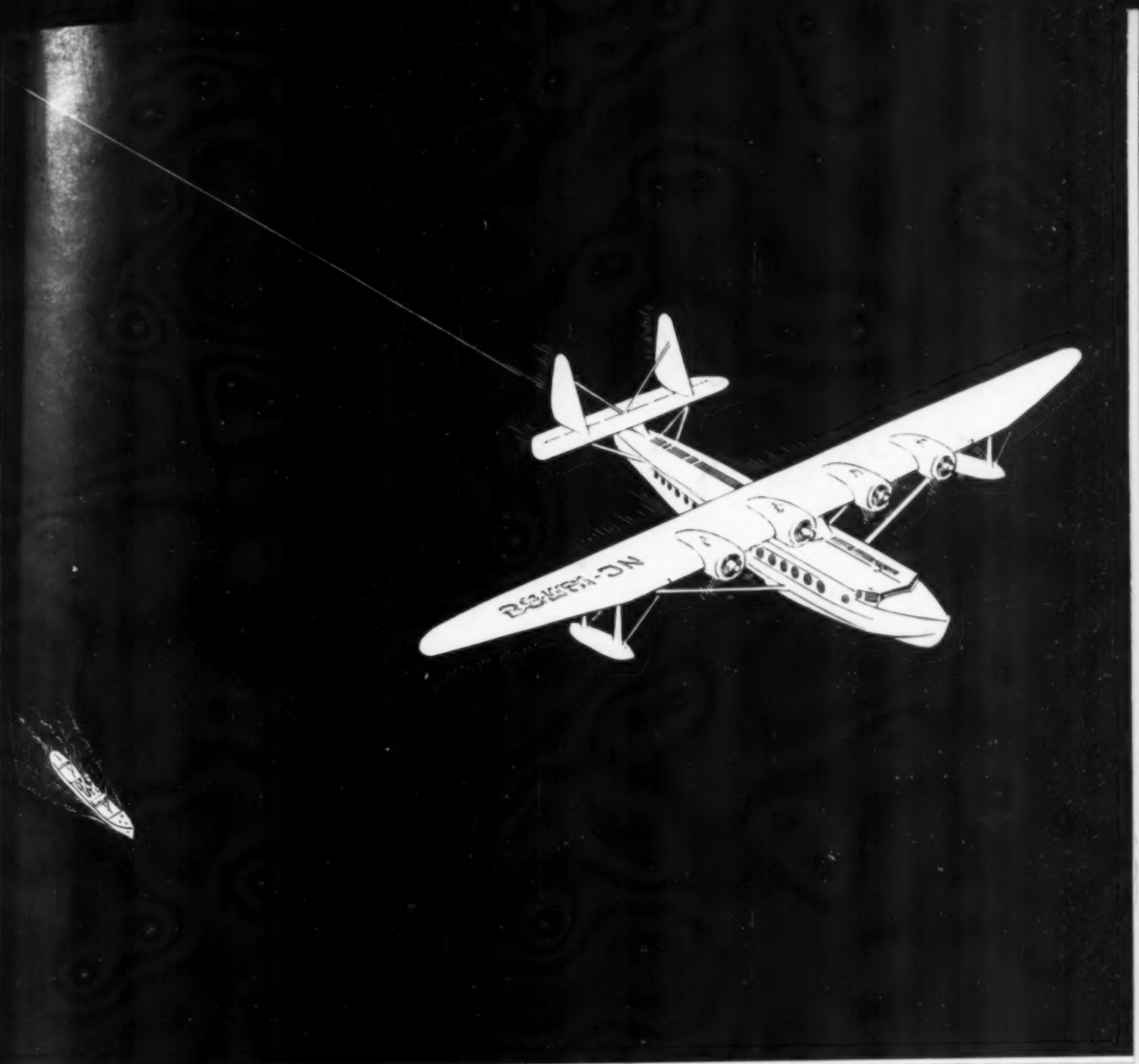

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METAL PROGRESS

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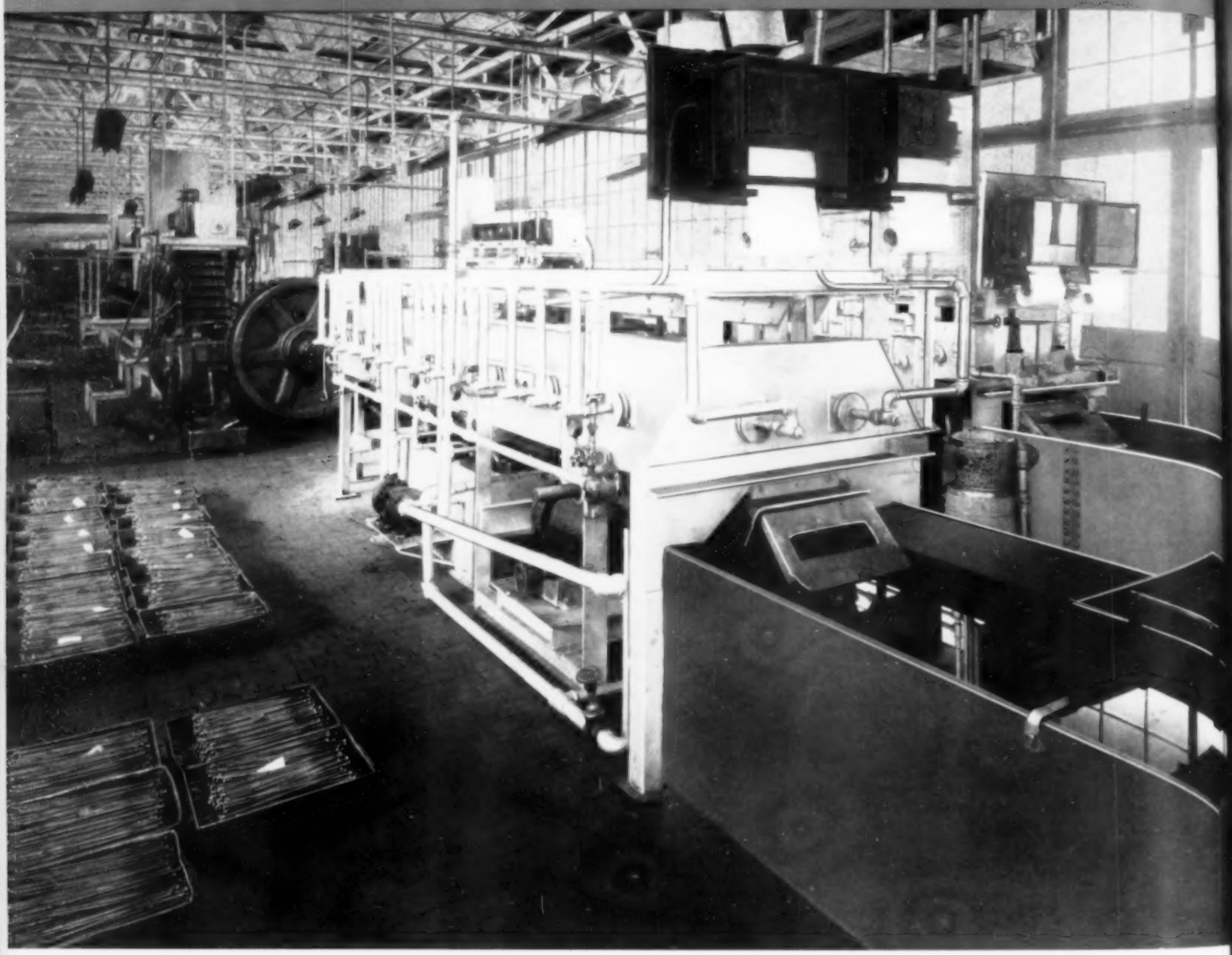
VALVE PUSH RODS ARE HARDENED IN 2 MINUTES



● Many restrictions surround the design, construction and erection of a modern heat treating furnace—but regardless of limitations, SURFACE COMBUSTION engineers build the furnace to handle the job as specified. Here, as in many other instances, economy of space, adaptation to production line efficiency, and high speed, dictated design. In this SC Slot Hardening Furnace (Double Unit) one of the largest production motor car manufacturers solved a problem with the aid of SC Engineers.

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Builders of **ATMOSPHERE FURNACES and HARDENING, DRAWING, NORMALIZING, ANNEALING FURNACES for CONTINUOUS or BATCH OPERATIONS**

contents of

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November, 1938

Volume 34, No. 5

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The black and white drawing for the front cover was kindly loaned by Koppers Co., American Hammered Piston Ring Division

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Notes on the convention

A PLEASANT COINCIDENCE was noted in many congratulations to WILLIAM PARK (Bill) WOODSIDE, ⊕ president elect, to the effect that one of the Founder Members should be honored with the presidency on the date the Society came of age and in the city of its birth. Without detracting from the deservedness of these compliments, and solely in the interests of historical accuracy, it may be put on record that the Detroit convention was the 19th annual convention of the consolidated organization, and the 20th annual exhibition held under the direction of the perennial ⊕ secretary, WILLIAM HUNT (Bill) EISENMAN, whereas the age of the Society as measured by the foundation of one of its component parts is different again. These things may be computed from the family tree.

Fellow Craft Club
First met in Detroit, Oct. 1913
Steel Treaters Club
Steel Treaters Research Society of Detroit
Steel Treaters Research Society
Incorporated in Detroit, April 1918
Steel Treaters Research Society
(Chicago Section) Established
1917
American Steel Treaters' Society
Organization meeting at City Club,
Chicago, Sept. 18, 1918
First exhibit at 7th Regiment Armory
Chicago, Sept. 24-27, 1919
(53 exhibitors)
American Society for Steel Treating
Consolidation effected in summer of 1920
First convention Sept. 14-17, 1920
in Philadelphia
American Society for Metals
Name adopted with new constitution,
Dec. 20, 1933

⊕

"Coming of Age" is at a certain birthday, which legally varies from place to place, but is essentially when the person is able to take care of his own affairs. That the American Society for Metals is "of age", in this sense, no one can doubt. Membership reached new peaks, both average for the fiscal year, 10,300 (as compared with 9150 for 1937) and all-time high of 10,942 in March. Since Society activities are based on membership, maxima in other statistics of ⊕ affairs are not surprising. Financially the Society is in most excellent shape, Treasurer Stoughton's audited report, with comparisons to fiscal 1937, showing a gratifying gain in assets and surplus achieved during the recent "recession", which roughly corresponded with the Society's fiscal year. Prospects for the immediate future are also good, as measured by space sales in the 1938 Exposition and advertising in the October issue of METAL PROGRESS.

Almost all of the chapters are comfortably solvent in their own right, their net cash assets totaling approximately $68,000.

⊕

Kudos. Deserved honors were distributed by the societies in this congress assembled. The American Society for Metals bestowed for the fourth time in history its highest honor, the Albert Sauveur Achievement Award; HARRY W. MCQUAID was the recipient, and the presentation was made, pleasantly enough, by Professor SAUVEUR himself. Past-President BAIN's citation and the classic paper on soft spots in abnormal steel by MCQUAID and EHN will be printed in the January issue of METAL PROGRESS. Other ⊕ awards were the Henry Marion Howe medal for the best technical paper to appear in *Transactions* to JOSEPH WINLOCK and RALPH W. E. LEITER ("Some Factors Affecting the Plastic Deformation of Sheet and Strip Steel, and Their Relation to the Deep Drawing Properties"), and the President's Bell for outstanding services to the Los Angeles Chapter.

American Welding Society awarded the Samuel Wylie Miller Memorial Medal for meritorious contributions to the science and art of welding to JOSEPH W. MEADOWCROFT, and the Lincoln Gold Medal for the best paper in the *Journal* to JAMES C. HODGE and CORNELIUS R.

SADLER ("Weldability and Properties of Materials for Casing Strings").

For the most meritorious contribution to the literature on wire manufacture or fabrication, the Wire Association awarded its medal to WALTER R. BLOXDORF for his paper on "Rope Wire" before the Thursday session.

Exposition. As to the National Metal Exhibition, it must be seen to be appreciated! This one, as well as the pre-depression show in 1927, filled the Detroit Convention Hall to capacity. Actually, Convention Hall is an assemblage of five interconnected buildings, so a good view could not be had from any single vantage. It required but a little perambulating to convince an observer, however, that if the exhibits had been installed in a mammoth auditorium, as at Atlantic City, it would be judged instantly as the most colorful and attractive. Comparisons would be invidious, but the leading steel manufacturers, metal companies and welding firms again led in the matter of eye appeal. A majority of all exhibits showed every indication of careful planning by expert showmen, shop-built and sent to the hall crated in units, so assembly was fairly rapid and simple. Actual registration was just short of 20,000; admission was to registrants by ticket and badge exclusively, so the hall was never over-run by the curious and the callow. Such a select attendance pleased the exhibitors, who were practically unanimous in saying they had interviewed the right people.

Tool Hardening. Toolsteels and their treatment are now, as 20 years ago, the subjects for most animated conversation. Discussion of W. R. BREELER'S paper on Tuesday morning ("Development in Molybdenum High Speed Cutting Steels") had to be cut short by the chairman, but was continued in the corridors and at the Metal Exposition almost without limit. It would appear that Emmons' introduction of the molybdenum-tungsten high speed steel about five years ago has been followed by many attempts to "improve" the analysis, just as similar attempts were persistently made after the disclosure of the Taylor-White tungsten-chromium high speed toolsteel early in this century. Breeler's conclusion is that while tungsten plus molybdenum should total at least 9%, the proportions of the two may be varied considerably from the "much molybdenum, little tungsten" which represents the least expensive combination of ingredients. J. P. GILL also spoke highly of a widely used variety containing no tungsten at all, but about double the ordinary vanadium (analysis as shown in his classification on page 313 of October METAL PROGRESS).

Many of these metallurgical permutations seem to be inspired by a desire to avoid a supposed susceptibility to decarburization of the molybdenum high speed during heat treatment. Proponents of the conventional tungsten high speed steels say that this added susceptibility is real; proponents of the newer molybdenum high speed steels say it is mostly a bug-a-boo, and that five or six atmosphere furnaces or salt baths shown at the Exposition will harden either variety without *any* decarburization — essential, of course, for fine tool work. Fortunately for this commentator, he does not need to buy toolroom equipment, just now, for every such manufacturer he interviewed (and there were more than half a dozen) was willing to admit that his furnace, atmosphere or salt bath was able to do just that, and most of them inferred that his furnace, atmosphere or salt bath was the best for the purpose — all things considered!

Ingot Practice. Iron and Steel Division and Institute of Metals Division (both of American Institue of Mining and Metallurgical Engineers) held meetings and a dinner during the first part of the week. Much to be regretted was the absence of many English friends. An extended tour by the British Iron & Steel Institute and the British Institute of Metals was to have placed the travelers in Detroit for National Metals Week, but at the last moment, just before the first contingent was to have sailed, the entire trip was canceled through fear of the impending Czechoslovakian crisis.

In their technical sessions both the American divisions went scientific. This is not an innovation for the non-ferrous group, but it is something rather unusual for the iron and steel boys to concentrate on the physical chemistry of steelmaking. The high spot, figuratively and scientifically, was reached by AXEL HULTGREN of the Metallographic Institute, Stockholm, who presented (in perfect English) an account of studies on the "Solidification of Rimming Steel Ingots" financed by the Swedish Ironmasters' Association, Jernkontoret. This is a worthy accompaniment of the much more extensive work on ingot practice being done by a committee of the British Iron & Steel Institute, and constitutes a body of information that the progressive steelmaker cannot ignore.

Hardenability. Much interesting information on hardenability was presented in a three-session symposium held by the . Perhaps the

outstanding papers were one on the mechanism of the crystallographic changes in austenite by Robert F. Mehl, another giving quantitative data correlating hardness, size of piece and quenching velocity by Marcus A. Grossmann and associates, and the third on hardenability of plain carbon steels by Messrs. Burns and Riegel. A summary of the entire matter has been promised the Editor; it may be said that enough data are available so that a systematic and quantitative appraisal may now be made of several much-used qualitative terms. Even yet there is some systematization to be done; for instance, "steel hardened to the center" may mean to one author a steel that shows no coarse fracture at the center of the bar, to another author a minimum hardness at center of C-53, to another a microstructure with well over 50% martensite, and to yet another "full hardening" means to within three numbers of the maximum Rockwell C-scale hardness. Let it not be thought that nothing yet remains to be learned, for Walter Jominy pointed out that 95% of the steel heats tested in the General Motors laboratories will harden correctly if the conventional chemical analysis and the grain size are correct, but 5% of such heats still go wrong!

Physics of Metal. An evening conference, prior to this series of meetings, was held in an attempt to draw from some learned physicists a scientific view of the true nature of hardness. To a metallurgist it is quite simple; obviously, hardness is what the testing machine measures. Possibly because they are intimidated by the usual methods of measuring hardness, physicists seem instinctively to correlate hardness with resistance to permanent deformation, and therefore quickly start to think about interatomic forces and the laws and actions responsible for plastic deformation and resistance thereto. Resistance to permanent deformation of an aggregate of metallic crystals is easily determined in a tensile or compressive test, but unfortunately hardness is not so simple as that, for the correlation between Brinell hardness (say) and ultimate strength in tension (which the physicist would say is related to cohesive strength) is much closer than a correlation between hardness and the point where plastic deformation starts (elastic limit).

From a practical viewpoint it is no objection that the ordinary hardness test does not measure a simple property, but a combination of several. Since the test is largely used as a check on uniformity, the result will show measurable variations from standard if any one of three or four inherent and fundamental properties varies to any great degree. One misapprehension existing in many physicists contributing to this discussion should be corrected: Metallurgists, at least, rarely try to predict the properties or utility of a metal by its hardness. Almost always a good metal and fabrication process are discovered by some other means and proven in service; thereafter hardness is one great help in assuring the fabricator that new parts, supposed to duplicate the successful ones, actually will do so.

Electrical Welding has grown to such importance and is applied to such large work that the capacity of the equipment and its effect on the power network frequently causes serious concern. For instance, the manufacture of Chrysler rear axle housings, as described to the American Welding Society by E. L. Bailey and V. Knecht, involves the butt welding of longitudinal edges of two long steel stampings. In the original machine 2000 hp. of direct current was needed for 7 sec. and one axle was made per minute. This gives a very low power factor for the load, and to minimize the surges in the power system a motor-generator set was installed and the circuit closed (when welding was to be done) by switching on the exciter motor — a method which would build the load up rather gradually. Later developments have included a new design of rear axle with somewhat thinner walls requiring less power to weld, use of two welding machines interlocked to avoid simultaneous action yet capable of producing 240 units per hour, and addition of auto-transformer and condenser banks to improve the electrical conditions. The result is that the peak power drawn from the line is only 1250 hp., at a power factor of about 85%.

Prof. Comfort A. Adams cited three recent instances where the problem had been given much study. In one butt welder for large condenser tubes 3000 kva. were required for 20 cycles, which was about the limit for the nearby network, for it caused a drop of 1 volt at the central station. These allowable momentary loads vary in magnitude, of course, as to the capacity and reactance of the supply system and the permissible disturbance. The maximum for the Detroit system is estimated at 12,000 kva., whereas in an installation for bright annealing tubing (requiring 5 sec.) 2000 kva. was the maximum permissible in a plant near Youngstown. Disturbances would be much more serious in a plant with its own power house, but the approximate result can be computed from an accurate map of the system.

Molder at Chevrolet-Saginaw

Within the last generation engineers have done much, by sand control and mechanization, to take the rule-of-thumb and back-breaking labor out of molding. Within the next generation, metallurgists will doubtless solve the riddle of "inheritance" in pig iron by pursuing such studies as the ones outlined by Mr. Boegehold in the Campbell Memorial Lecture

By A. L. Boegehold
Head, Metallurgical Dept.
Research Laboratories
General Motors Corp.

some unusual aspects of Malleable Iron melting

FIFTEEN YEARS AGO most of our malleable iron was melted in air furnaces. For the general run of automotive castings it was necessary to hold the carbon not over 2.60% and the silicon not over 1.00% in order to obtain a white fracture in all castings. Even when composition was held within this range, every heat was tested to be sure that the iron was sufficiently free from primary graphite to make good malleable after annealing. Without knowing why some heats of the proper composition showed too much graphite in the form of mottles, the metallurgist could always make the necessary adjustments in composition to get the desired fracture. These variations were blamed on oxidation, moisture in the atmosphere, and something in the melting stock.

When the duplex process for making malleable iron was instituted involving melting in a cupola, followed by heating to casting temperature in a direct arc electric furnace, we received additional manifestation of how little we know about the causes for white fracture. Instead of a total carbon plus silicon of 3.50% to which air furnace iron was limited, duplexed iron could contain 2.75% carbon and 1.25% silicon, a total of 4.00%. The upper limit for carbon and silicon in duplexed iron will fluctuate the same as in air furnace iron except that the range of fluctuation is at a higher level, but the true causes for this fluctuation are no better known than they are in the air furnace process. The magnitude of the variation in carbide retaining power of hard iron as regularly made in production is illustrated in the first figure which shows fractured pyramid castings that disclose several interesting facts:

1. The cupola iron shows considerably less carbide retention than the iron after heating in the electric furnace. Castings of two sizes were used but comparison may be made at like sections, for example at 2 in.

2. The mottled structure in the cupola metal consists of gray areas of much smaller diameter than in the electric furnace metal.

3. The castings made 7 hr. after the first two were cast show decidedly less carbide retaining power than the first two, although they are almost identical in composition (as to C, Si, Mn, S).

4. The reduced carbide retaining ability in the second pair of castings is similar in both cupola metal and electric furnace metal — suggesting the origin of the influence in the cupola melting process.

5. The electric furnace iron cast 9 hr. after melting started shows some of the small diameter mottles which characterize the cupola metal.

Although carbide retention in the second electric furnace casting was toward the low side, it still had sufficient freedom from mottling in the 1½-in. section to be satisfactory for making the regular run of production castings. The magnitude of this structural variation had not formerly been realized because fracture tests were always made on a sprue 1⅝ in. in diameter at the midpoint. These pyramid castings fractured longitudinally give much more extensive information. It now seems evident that annealing would be faster if the causes for increasing carbide retentivity with high silicon content were better understood so it could be

Excerpts from Edward deMille Campbell Memorial Lecture for 1938

2 HRS. AFTER MELTING STARTED		9 HOURS AFTER MELTING STARTED	
CUPOLA IRON	ELECTRIC FURNACE IRON	CUPOLA IRON	ELECTRIC FURNACE IRON
2.79% C	2.71% C	2.80% C	2.75% C
1.11% SI	1.16% SI	1.25% SI	1.18% SI
.37% MN	.37% MN	.41% MN	.40% MN
.11% S	.11% S	.11% S	.11% S

Pyramidal Castings From Regular Production Split to Show Ability to Retain Carbides in the White Iron

accurately controlled; therefore it is somewhat surprising that so little work has been directed at this problem.

Our interest started from a laboratory experiment. We made some alloy malleable iron in a high frequency induction furnace with a composition which by comparison with the production iron should have been white in a 2-in. round section. The fracture of this iron in a 2-in. round, however, was not white nor even speckled, but all gray. The same result was obtained when a melt was made with the same composition as the production metal! This convinced us that our knowledge as to principles was sadly lacking. Without being able to duplicate production results in laboratory melts, it would be impossible to develop alloys in the laboratory that could be used in production.

The method of attack consisted of making a large number of exploratory melts under increasingly accurate control, to which additions were made and treatments given in an endeavor to obtain some clues as to measures that would increase carbide retentivity. Naturally, the things we tried were those that have been reported to have a stabilizing effect on the carbide. We found after many vain attempts to obtain white fracture that most of the factors which have been said to promote carbide retention in iron seemed to be devoid of that power. Part of this paper then becomes a partial case history of our attempt to make white iron in the laboratory (using a high frequency induction furnace) of the same composition as employed in the cupola-electric furnace production method of melting in malleable foundries.

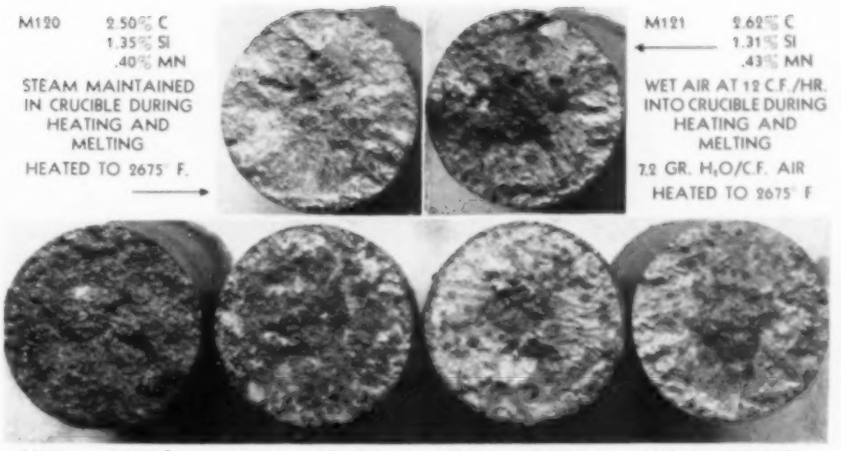
First experiments duplicating the composition of commercial white iron castings contained 2.76% C and 1.21% Si and were made from steel scrap, ferrosilicon and carbon added as graphite. When cast into a green sand mold, a 2-in. round casting was completely gray. In the next experiment the carbon was all added as cementite in wash metal, and the melt was made under dry hydrogen. It also was completely gray. Other melts were made with additions of steel, the carbon going down to 2.40% and the silicon to 1.00%, yet they were gray. It is obvious then that some unknown strong graphitizing influence was operating in our laboratory procedure to prevent white fracture in the castings.

Since there has been evidence in production and in the literature that moisture in contact with molten iron causes an increase in carbide retentivity, we tried this in charges where there was no primary graphite in the raw material to promote a gray fracture in the casting. Moist air bubbled through the melt for 8 min. gave a gray casting, but when steam was used for 1 min. the fracture was completely white (analysis: C + Si = 3.79%). Here was the first evidence supporting the idea that moisture increases carbide retentivity in cast iron and the first result that was in accordance with what should have been expected from our prior knowledge.

Subsequent heats produced erratic results when the iron was only heated to 2650° F., so it was decided to try higher temperatures such as used in electric furnace heating of the commercial iron. The higher temperature seemed to promote white fracture, but one previous melt at 2640° F. showed a greater amount of white fracture than any other iron of the same total carbon plus silicon from the hotter casts.

Up to this point no mention has been made

of any possible effect of moisture in the atmosphere. It must be true, however, that at all times during melting the atmosphere is continually circulating throughout the charge in the furnace due to convection currents (even though the crucible containing the charge in our experimental furnace was covered) thus bringing in contact with the large amount of surface of the hot charge a continual stream of moisture. If oxides formed by bubbling steam through the melt will cause white fracture, then a continual oxidation of the hot metal's surface by moist air and a reoxidation of this surface as melting proceeds should have a similar effect.


M120 2.50% C 1.35% Si .40% MN
STEAM MAINTAINED IN CRUCIBLE DURING HEATING AND MELTING
HEATED TO 2675° F.
M121 2.62% C 1.31% Si .43% MN
WET AIR AT 12 C.F./HR. INTO CRUCIBLE DURING HEATING AND MELTING
7.2 GR. H2O/C.F. AIR
HEATED TO 2675° F
M130 2.70% C 1.26% Si .41% MN
DRY AIR THROUGH ACT. Al2O3 INTO CRUCIBLE AT 6 C.F./HR. DURING HEATING AND MELTING
HEATED TO 2760° F.
M130-1 2.70% C 1.26% Si .40% MN
HEATED TO 2860° F.
POURED AT 2700° F.
M130-2 2.70% C 1.26% Si .40% MN
HEATED TO 2910° F.
POURED IMMEDIATELY
M130-3 2.39% C 1.26% Si .40% MN
METAL IN LADLE LEFT FROM M130-2 COOLED TO 2700° F. AND POURED

Representative Tests Showing True Action of Moisture When the Inoculating Effect of Solid Iron Oxide Picked up From the Containers Is Excluded

A series of melts was then made where various gases, both dry and moist, were introduced into the crucible during melting and it gradually became apparent that *moisture*, even the little carried by the ordinary air at normal humidity, had strong power to retain carbide during solidification. Thinking that this must be due to the formation of metallic oxides by decomposition of H_2O, a melt of iron which had been treated with moisture until the casting was verging on all white had 0.50% Fe_3O_4 added to it. This oxide appeared to dissolve immediately in the molten metal but contrary to our expectations, instead of making the iron whiter, it turned it completely gray. This was an absolute reversal of the expected result; while most of the experiments had gone contrary to expectations we were beginning to think the furnace was bewitched when iron oxide caused graphitization!

It has always been reported (and we confirmed it) that the addition of iron oxide to molten iron increased its tendency to chill but here was a case where iron oxide acted as a graphitizer. Because we knew that oxides either from moisture or oxide additions would increase carbide retention in cast iron when it solidified rapidly as in light sections or against chillers, we have been assuming all along that these oxides would have the same action in low carbon, low silicon iron which had solidified slowly. We have seen that this assumption is erroneous.

Upon realizing that oxide of iron acted as a graphitizer under certain conditions, we scrutinized our procedure to detect where contamination by oxide might occur, and found that the small amount retained in the melting crucible was sufficient. We looked further and found a similar condition in the transfer ladles which retained small particles of oxidized metal embedded in the inside surface. We therefore in subsequent experiments relined all crucibles and ladles with clay and preheated them to 1700° F. prior to each use.

Irons which were partly gray, as cast, from picking up iron oxide had mottles small in size, a characteristic of iron we intentionally graphitized with iron oxide. This is a matter of considerable importance in subsequent annealing. The white fractures of the castings poured from freshly clay-lined crucibles were in striking contrast to the gray fractures obtained with previous heats of similar composition or of lower total carbon plus silicon. Further to control the effect of variable humidity in the air a melting procedure was adopted whereby the desired type of atmosphere was supplied in a continuous stream into the crucible at a sufficient rate so that none of the extraneous atmosphere could intrude.

With this type of control it was possible to obtain more concordant results, and they indicated that moisture and hydrogen have a positive power to overcome the graphitizing influence of increased carbon and silicon. The prevention of contamination by solid iron oxide is even more important to the production of

white fracture with high silicon and carbon than is the presence of moisture. The powerful carbide retaining effect of moisture when the graphitizing influence of solid iron oxides is excluded is shown in the view at the top of page 559 with its caption. In either heat M-120 or M-121 the fracture was completely white when the iron was heated to only 2675° F. and exposed to a steam or a moist air atmosphere (in the latter case air was bubbled through water at 180° F.).

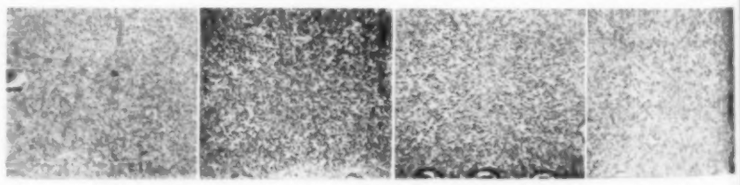
This is certainly a remarkable difference to prior heats made under the same conditions, except that the iron was handled in crucibles previously used, and wherein the fracture was completely gray. The difference in carbide retentivity is as great as that represented by the difference in behavior between air furnace malleable iron and duplexed cupola furnace malleable iron.

It is not contended that the carbide retentivity in cupola malleable iron is the result of large quantities of moisture in the atmosphere. The pronounced difference between crucible melting and cupola melting is to be found in the degree of exposure of the molten metal and the charge to gaseous elements. In the cupola there is a constant rush of gases at high velocity coming in contact with the charge being heated and with the molten metal broken up into small drops presenting a tremendous surface area for reaction with these gases. It is believed that the concentration of moisture in the gas is not as important as how much moisture is brought into contact with each unit weight of molten metal. The cupola gases need contain only a small amount of moisture in order to have each unit weight of molten iron come in contact with just as much water as could be obtained in a crucible melt by having a gas highly saturated with moisture in contact with the charge.

In the view on page 558 it will be seen that the pyramid castings made from cupola metal which had not been superheated in the electric furnace showed a greater mottling tendency and small diameter mottles characteristic of a metal to which iron oxide had been added. It is believed that this is not an indication of the result of anything that happened in the cupola. The metal for casting these pyramid castings was procured by pouring from a 5-ton transfer ladle into a hand shank ladle. It is entirely possible and probable that this hand shank, having been used for making other castings, contained some oxidized metal capable of inoculating the contents sufficiently for the increased amount of mottling. On the other hand, the molds for pyramid castings made from electric furnace iron were placed on the production conveyor line and received metal from the regular pouring ladles, which are kept replenished with hot metal frequently enough so that they always contain molten metal and there is no opportunity for contamination with solid iron oxide.

The view on page 559 also shows comparison fractures made from iron melted under *dry* air (heat M-130). With a total carbon plus silicon of 3.96%, the fracture was gray even when heated to 2760° F. and, even when superheated to 2860° F., the fracture contained only about 25% white. By heating to 2910° F. and pouring immediately, the fracture was practically all white and when allowed to cool to 2700° F. and cast it was still all white and did not show the ring of gray which characterized the iron cast from 2910° F.

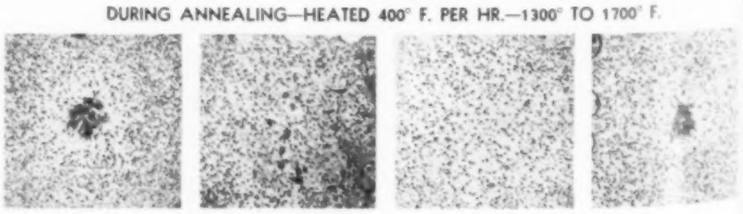
Obviously, white fractures may therefore



DURING ANNEALING—HEATED AT 36° F. PER HR.—1520° TO 1700° F.

HH	JJ	LL	MM
2.76% C	2.80% C	2.84% C	2.72% C
1.10% SI	1.09% SI	1.07% SI	1.03% SI
.37% MN	.36% MN	.36% MN	.34% MN
.11% S			
.05% P			
NO FE_2O_3 ADDED	0.25% FE_2O_3 ADDED	0.75% FE_2O_3 ADDED	1.00 FE_2O_3 ADDED

DURING ANNEALING—HEATED 400° F. PER HR.—1300° TO 1700° F.



Annealed Malleable Bars, Showing Effect of Iron Oxide on Distribution of Graphitic Spots

be obtained by heating to 2900° F. with a composition as high as 3.96% total carbon plus silicon if contaminating solid oxide influence is prevented.

The chief culprit responsible for gray fracture with low carbon plus silicon appears to us to be solid iron oxide. That this is true for air furnace melting, appears plausible when we remember the universal custom of emptying the air furnace with hand shank ladles while the stream runs continuously out of the furnace, necessitating a long line of pourers waiting their turn to catch a ladleful and, while waiting, the residue clinging to the ladle lining oxidizes and prepares to do a good job of inoculating a perfectly good white iron coming from the furnace.

Fast Annealing

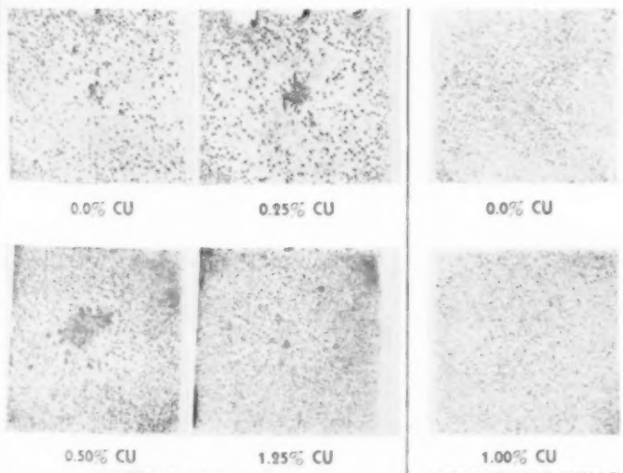
The importance of being able to obtain white iron with a high carbon plus silicon content obviously resides in the shorter time required for annealing. The time required to convert white iron to malleable iron by annealing has been progressively reduced during the past 15 years as a result of a study of the time to reach equilibrium at various stages of the annealing process, by reducing the mass of pots and castings closely stacked together through which heat had to penetrate, and in some instances by increasing the silicon content of the iron at the expense of a reduction in carbon content.

The lighter the casting and the faster the metal solidifies, the higher may be the silicon content without formation of primary graphite in the casting and consequently the faster will the annealing be completed. Following this relationship still further, we find that still more rapid solidification such as that obtained in a metal mold permits the use of such high silicon content that it becomes only necessary to heat the casting up to 1700° F. and allow it to cool to obtain complete annealing.

We are ordinarily concerned, however, with the production of castings in sand molds, sections up to 1 in. thick which solidify at a rate comparable with that of a 2-in. round bar. For this purpose, iron melted in the cupola with a charge of steel scrap, foundry returns, and silvery pig iron, and heated to pouring temperature in a direct arc electric furnace, may contain 2.70 to 2.75% carbon, 1.15 to 1.20% silicon, 0.38 to 0.42% manganese, about 0.05% phosphorus and 0.09 to 0.11% sulphur, and will usually produce a white fracture in a 2-in. round casting. Response of these castings to annealing treatment varies more than could be explained by variation in analysis; and the causes therefor may possibly be closely related with the causes of carbide retentivity during solidification. Since we have discussed at some length the effect of adding iron oxide to molten iron upon solidification structure in laboratory melts, the picture should be completed with its effect on production iron, both as to solidification and as to response to annealing.

The four square sections at the top of the view on page 560 show the effect of iron oxide additions upon the formation of temper carbon when the heating to 1700° F. at the beginning of the annealing cycle is at 36° per hr. from 1520 to 1700° F. (This heating rate has been adopted as standard because it produces fine, close-packed temper carbon spots and consequently facilitates rapid annealing.)

It will be observed that even with this slow heating the iron oxide additions tend to make the temper carbon spots larger and further apart, especially toward the center of the casting where the solidification rate is slower. When the same castings are heated at 400° per hr. to 1700° F. in the annealing cycle, as in the lower four sections, the iron oxide has a similar influence and makes the temper carbon distri-



Pig Irons Are Inherently Different in Response to Annealing (Heated From 1300° to 1700° F. in 1 Hr.). Closer spaced graphite areas permit a faster annealing cycle

bution even less desirable than the regular iron shows after this fast heating.

The speed of carbide elimination in annealing when heated rapidly to 1700° F. is apparently a function principally of the size and distance between temper carbon spots, and this appears to increase directly as the amount of iron oxide added. After the castings have been subjected to the standard annealing cycle (which includes heating at 36° per hr. from 1500 to 1700° F., holding for 8 hr. at 1700° F., cooling to 1400 in 2 hr. and cooling from 1400 to 1300° F. at 7° per hr.), the temper carbon spots are greatly enlarged by the iron oxide addition. (See the three microsections reproduced below.) Although this apparently has not retarded decomposition of massive cementite enough to prevent complete elimination in 8 hr. at 1700° F., it has, however, retarded second stage graphitization to the extent that considerable pearlite remained after cooling at 7° per hr.

Contradictory Actions of Iron Oxide

We see, therefore, that the action of iron oxide additions is to increase the tendency to mottle and at the same time make it more difficult to anneal, which is contrary to the characteristics that would result if increased mottling tendency were produced by the addition of some graphitizing agent such as silicon or copper. With the addition of such elements, the mottling tendency would increase so that the iron would be only useful in lighter sections, but because of the addition of these graphitizing agents the rate of carbide elimination in annealing would be speeded up. We see, therefore, that additions cannot be merely referred to as "carbide stabilizing agents" without specifying whether they stabilize carbides during solidification or during annealing, or both.

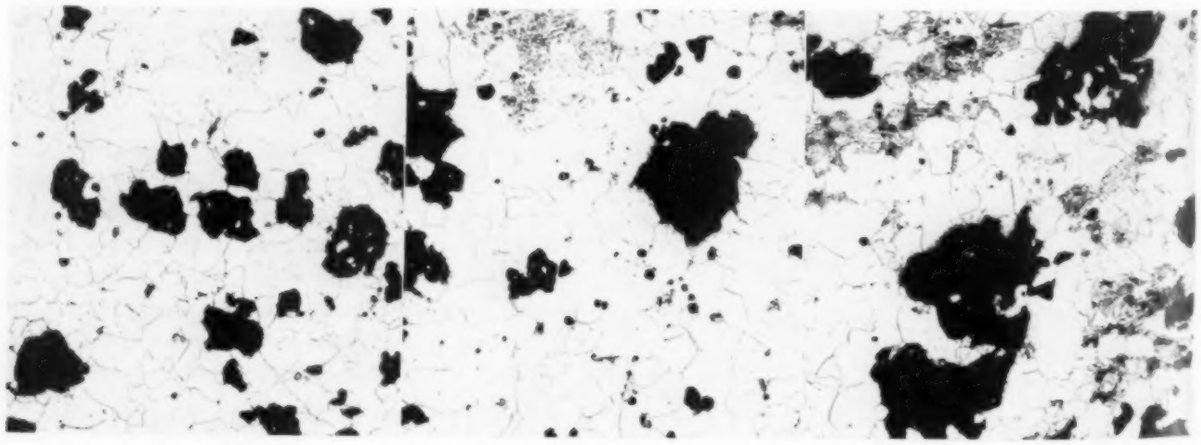
In the case of iron oxide, we have the paradoxical situation of a material that has a net influence like a graphitizing agent during solidification but which acts like a carbide stabilizer during annealing.

The practical control of the iron to obtain close-packed temper carbon spots even when the annealing cycle includes rapid heating to 1700° F. is by means of selecting the silvery pig iron used for 12½% of the cupola charge. It is not known what factor in the pig iron is responsible for this action but the desirable or undesirable characteristic can be obtained at will by merely switching pig irons.

The importance of having constant raw materials in experimentation is a truism, and it has lately been shown that there is an inherent difference in pig irons used for the manufacture of malleable. A good example may be shown from some experiments on the effect of copper in malleable iron. Note the difference in temper carbon distribution occurring after rapid heating to 1700° F. in the annealing cycle in the view on page 561, which shows that in iron made with pig iron 'A' the temper carbon is coarse and sparse in contrast to the fine, densely packed temper carbon in the cast from pig iron 'B' (no copper in either case).

The 'A' iron is the same type as the iron discussed by the author earlier this year in "Factors Influencing Annealing Malleable Iron" before the American Foundrymen's Association. In those tests slow *(Continued on page 608)*

Microsection of Test Bars Annealed in Regular Cycle Showing That Iron Oxide Not Only Increases Size of Graphitic Areas but Slows Down Secondary Graphitization (Retains Some Pearlite Among the Ferrite)



Iron plus 0.10% Fe_2O_3 | Iron plus 0.25% Fe_2O_3 | Iron plus 0.75% Fe_2O_3

by E. K. Smith
Metallurgist
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Chromium Cast Irons

FOR YEARS chromium has been used in cast iron to obtain certain desired properties, but it is just recently that the actual effects of chromium have been determined more accurately. As mentioned by H. Bornstein in METAL PROGRESS for June 1933, chromium is a carbide former, decreasing the number and size of graphite flakes and favoring the formation of more and finer pearlite. These effects on the microstructure cause an increase in tensile and transverse strengths and hardness. Moreover, the carbides formed are extremely stable at high temperatures, and thus result in higher strength at elevated temperatures, and in less growth after repeated heatings.

With amounts over approximately 1% chromium (according to the base metal) there is a tendency to chill, due to the excess carbides present. For this reason, a graphitizing element, such as nickel or silicon, is often added in conjunction with chromium, especially when the castings have thin sections. In fact, the greatest tonnage of alloy irons made in this country are the low nickel-chromium irons used for automotive cylinder blocks and other gas engine parts.

Let us now consider the iron castings with chromium up to 3%.

More accurate information as to the exact influence of small percentages of chromium in cast iron has been obtained from a large number of tests run during the past year by Union Carbide and Carbon Research Laboratories and others. In one series of tests on an ordinary grade of cupola gray iron, various amounts of chromium were added to different hand ladle samples taken from the same bull ladle. The ferrochrome used had the same carbon and silicon content as the base metal, thus avoiding any variation in these two elements. As the hand ladles were poured rapidly by a number of molders, pouring temperatures were practically constant. A digest of the results of these tests is given in the first table (page 564).

It will be noted that as chromium increased from 0.04 to 2.18% the combined carbon increased, and transverse strength increased to a maximum at about 0.50% chromium. Tensile strength and compressive strength increased continuously throughout the whole range, as might be expected. It is also interesting to note that the bar containing 0.77% chromium had higher impact value than the unalloyed bar.

The statement has been frequently made that chromium lowers resistance to impact. However, these and other new and accurate determinations show that, as has been predicted, chromium actually *increases* the impact resistance of cast iron until carbides begin to show up in the microstructure. This test confirms practical experience which has shown that, in general, the best physical properties coupled with good machinability are obtained at about the point where chromium carbides appear in the microstructure.

Microstructure — As chromium is a strong carbide forming element, its effect on microstructure can be fairly accurately predicted. When chromium is added to a very soft iron containing coarse graphite and ferrite, more and more carbon is retained in the combined form as the amount of alloy increases. This means that the amount of ferrite is decreased and the pearlite increased, until finally the entire matrix becomes pearlitic. The accompanying microstructures of the irons cited in the first table, containing 0.04% chromium and 0.77% chromium, show that the ferrite and large graphite

Effect of Chromium on Cast Iron

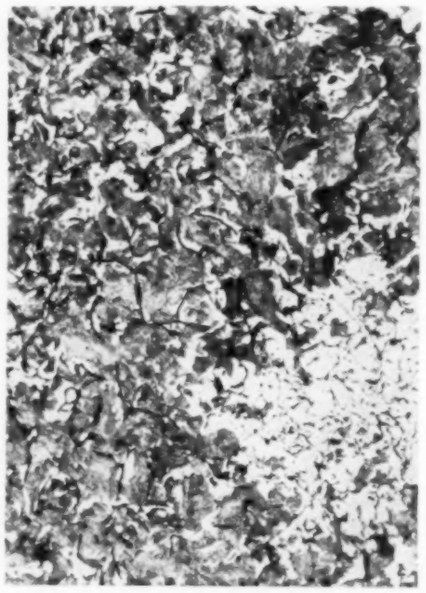
% Cr	% Carbon		Transverse (18 in.)		Tensile Strength	Compressive Strength	Brinell Hardness	Charpy Impact
	Total	Combined	Strength	Deflection				
0.04	3.43	0.36	2100 lb.	0.273 in.	27,000	94,250	163	37.6*
0.45	3.46	0.63	2675	0.280	33,800	122,200	207	30.0
0.77	3.45	0.70	2550	0.278	35,575	117,100	207	40.6
1.19	3.46	0.93	2350	0.263	36,050	121,200	235	34.0
1.36	3.40	0.94	2500	0.243	36,050	125,000	241	33.6
2.18	3.45	1.58	2000	0.169	37,150	143,300	302	30.6

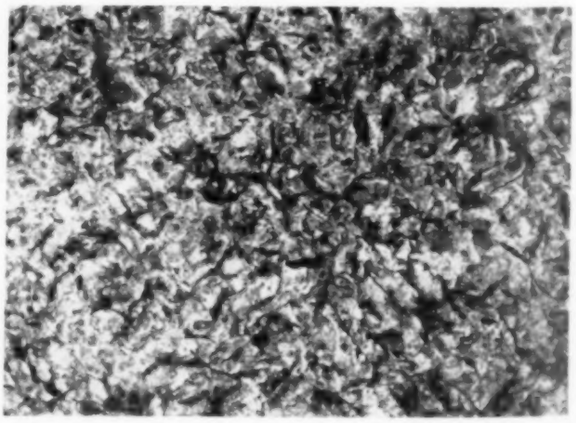
*Impact tests were made on specimens cut from transverse bars and ground to 1.17 in. diameter, 6-in. span and broken with 120 ft-lb. energy head.

are replaced by pearlite and fine graphite.

At some point in the addition of chromium, carbides begin to appear. This point naturally depends on the composition of the base metal, the section size, and cooling conditions. In a moderately hard base metal containing low carbon and low silicon, relatively small amounts of chromium will cause carbides to appear. On the other hand, where the base metal has high carbon and high silicon, and the sections are heavy, large amounts of chromium can be added without producing excessive hardness. For instance, in the tests with a soft iron base, the addition of 0.77% chromium raised the Brinell hardness number to only 207. No difficulty was encountered in machining the bar containing 1.36% chromium, which tested 241 Brinell.

As a general rule, carbides are noticeable when chromium is over 1.0%; castings with over 1.5% are usually mottled or white.





Left, Ferritic Structure of Unalloyed Base Iron, Containing 0.04% Chromium; Below, Pearlitic Structure of Iron Containing 0.77% Chromium. Both etched, 100×.

Applications of Low Chromium Irons

For Resistance to Wear — Since chromium increases hardness, it is used for castings exposed to abrasive wear. One of the best known applications for this purpose is in combination with nickel or molybdenum in automotive cylinder blocks and brake drums. Others include the following:

Chilled rolls: Cr 0.50 to 1.50, C < 3.50, Si 2.50%.
Cast gears: Cr 0.75, C 2.75 to 3.25, Si 1.50 to 2.50%.
Plowshares: Cr 0.75, C 3.70 (combined carbon 0.75), Si 1.10 to 1.25, Mn 0.50%.
Cement mill liners: Cr 1.00, C up to 3.50, Zr 0.10%.

In chilled iron, the use of chromium up to 1.0%, with 0.10 to 0.15% vanadium to give a finer grain structure and increased toughness, is becoming common. Castings made of this chromium-vanadium composition have a fine, hard chill which is particularly resistant to abrasive wear, and the remainder of the casting is readily machinable. The chills themselves are often made of chromium iron, with chromium from 0.50 to 1.50, carbon 2.90 to 3.25, and silicon from 1.50 to 2.50%.

Higher percentages of chromium (either with or without vanadium, nickel, or molybdenum) produce hard white irons which are very resistant to wear, due to the iron-chromium carbides present in the microstructure. An extremely hard iron containing 3% chromium and 1% molybdenum is used for valve seat

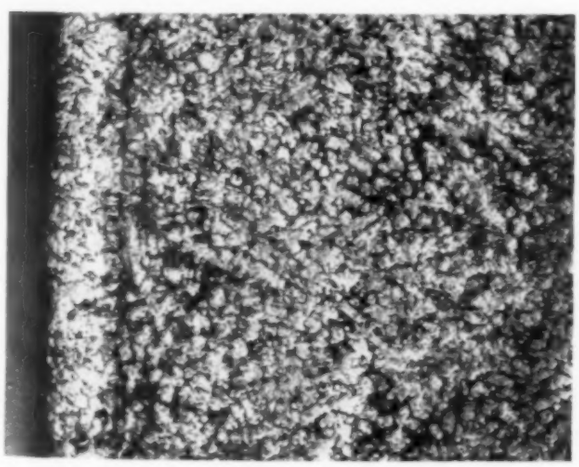
inserts. Another popular composition is "Ni-hard", with approximately 4.50% nickel and 2.50% chromium, which has a Brinell hardness number between 450 to 700 depending on section and treatment.

Small amounts of boron added to chromium cast iron impart extreme hardness, up to 800 Brinell. Several new alloyed compositions containing chromium and boron are being used for resistance to severe abrasion.

Another wear resistant material is "Nitricastiron", a nitrided cast iron. The analysis usually runs about 1.25% chromium, 1.00% aluminum, 0.25% molybdenum, 0.15% vanadium, and 1.25% silicon, with carbon around 2.75% to 3.00% and phosphorus and sulphur held very low. Castings poured of this mixture are annealed, machined, and then nitrided. The extremely hard nitrided case produced is shown in the micro on this page. Such castings are finding many applications, especially in the oil fields for pump parts and liners.

For Resistance to Heat — Because the chromium carbides and pearlite are extremely stable at high temperatures, chromium is very effective in reducing the growth and distortion of gray iron after repeated heatings. About 1.0% of chromium will effectively retard growth up to around 1400° F. Chromium irons also have higher tensile strengths at elevated temperatures, and retain much more of their original strength afterwards than do unalloyed irons. In one test, an iron with 1.0% chromium and 2.3% silicon actually increased in tensile strength from 43,000 to 46,000 psi. after 60 5-hr. cycles to 1400° F., and microscopic examination showed that the structure was still pearlitic. Unalloyed iron submitted to the same heating cycles was, at the conclusion, completely ferritic in structure and full of voids due to loss of graphite.

Nitrided Case on Nitricastiron. Etched, 50×



Irons like the one mentioned above, with chromium about 1.0% and silicon from 1.75 to 2.50%, depending on the section size, are widely used for high temperature service. The higher silicon content prevents breakage, and the chromium is sufficient to retard growth at temperatures up to 1400° F. In the enameling industry, from 0.30 to 0.50% chromium is sometimes used in the cast ware to prevent warpage in the enameling process. Some typical analyses of heat-resisting irons are as follows:

Pots for molten metal: Cr 0.50 to 1.00, C up to 3.50, Si up to 2.50%.

Smoke box castings: Cr 0.50 to 1.50, C 2.75 to 3.25, Si 1.25 to 2.50%.

Glass molds: Cr 1.00, C 3.00 to 3.25, Si 2.10, Mn 0.60%.

Stoker links and grate bars: Cr 1.00, C 2.75 to 3.50, Si 2.50%.

Firebox grates: Cr 1.25, C up to 3.50, Si 2.25%.

High Chromium Cast Irons

Comparatively small amounts of cast iron containing between 3 and 12% chromium have been made, although in some cases this range with suitable carbon content gives excellent resistance to abrasion.

The great increase in tonnage of castings containing high percentages of chromium with relatively high carbon, which can be termed either cast irons or steels, has been a striking development of recent years. Chromium varies between 12 and 34%, with carbon from 1.00 to 3.50%. Experience has shown that the valuable properties of this family of alloys advance in very definite steps, roughly outlined as follows:

Chromium Content	Properties
From 12 to 20%	Resistant to abrasion and to oxidation
From 22 to 28%	Extremely resistant to oxidation and quite resistant to corrosion; can be heat treated for machining and then rehardened
From 28 to 34%	Excellent for resistance to oxidation and corrosion; almost stainless

Chromium 12 to 20%

A considerable quantity of this material is being cast at present for resistance to oxidation and abrasion. Research at Union Carbide and Carbon Research Laboratories has brought out a good deal of information on its structure and

properties. Typical examples which were cited in an address by S. M. Norwood before the Montreal Chapter ⚙ in 1933, are given below:

Properties of 18% Chromium Irons

	Heat I	Heat II	Heat III
Composition			
Carbon	1.87%	2.18%	2.86%
Chromium	17.42	17.50	17.00
Silicon	1.78	1.67	1.81
Manganese	0.58		
Properties as-cast			
Transverse strength (12 in.)	5485 lb.	6000 lb.	4000 lb.
Deflection	0.08 in.	0.13 in.	0.11 in.
Brinell hardness	418	415	444
Tensile strength		75,900 psi.	53,900 psi.
Izod impact (10x20 mm.)		3.25 ft-lb.	2.50 ft-lb.
Properties after annealing			
Transverse strength (12 in.)		5200 lb.	3700 lb.
Deflection		0.12 in.	0.11 in.
Brinell hardness		302	415
Tensile strength		90,000 psi.	31,670 psi.
Izod impact (10x20 mm.)		5.0 ft-lb.	1.5 ft-lb.

These bars were annealed at 1650 to 1800 F. and slowly cooled in the furnace. Tensile and impact specimens were machined from them without particular difficulty, using low spindle speeds.

The castings cited above contain higher percentages of carbon than are ordinarily found in this type of casting commercially made at the present time. Today most of these castings are made in the electric furnace, where carbon can be held to between 1.25 and 2.00%.

A very good property of the irons with 12 to 20% chromium is their high strength at high temperatures. Short time tensile tests have shown strengths of approximately 14,000 psi. at 1600 F. For service at elevated temperatures, it is better to keep phosphorus on the low side. Since such castings are usually made with steel scrap, however, the phosphorus is naturally low.

In regard to corrosion, these chromium "cast irons" are not so resistant to corrosion as the lower carbon alloy "steels", because, for a given chromium content, corrosion resistance decreases with rising carbon content. This decrease is due to the fact that chromium forms carbides, instead of remaining in solid solution where it is most effective for corrosion resistance. If rather complete resistance to corrosion is required, enough chromium should be added to provide at least 12% chromium in solid solution. Although cast irons containing 12 to 20% chromium do form a superficial coating of rust, the rusting is not progressive, and they give good service in certain corrosive conditions.

In regard to abrasion resistance, such irons seem to have a tendency to work-harden. For instance, a set of sand mullers containing 18% chromium wore more than a chilled iron set for the first two days, but after that the alloyed material seemed to stop wearing and continued in operation for weeks with only a little more wear. However, on account of the higher carbon, such chromium cast irons do not show nearly the resistance to impact that is exhibited by the lower carbon stainless steels.

Applications for castings with 12 to 20% chromium are numerous. Liners for high temperature kilns, plates for resistance to abrasion, annealing pots, and certain furnace castings are typical examples for high temperature service. This composition is also widely used for abrasion resistance at ordinary temperatures.

Melting Practice

In some cases, 15% chromium cast iron is melted in the cupola, using steel scrap and chromium briquets. Such castings contain from 2.85 to 4.00% carbon and are extremely hard, the Brinell being about 550. They show remarkable resistance to oxidation and abrasion, but are brittle in light sections because the high carbon produces massive chromium carbides. The castings are therefore used for applications where resistance to impact is not required, and otherwise where they can be well supported.

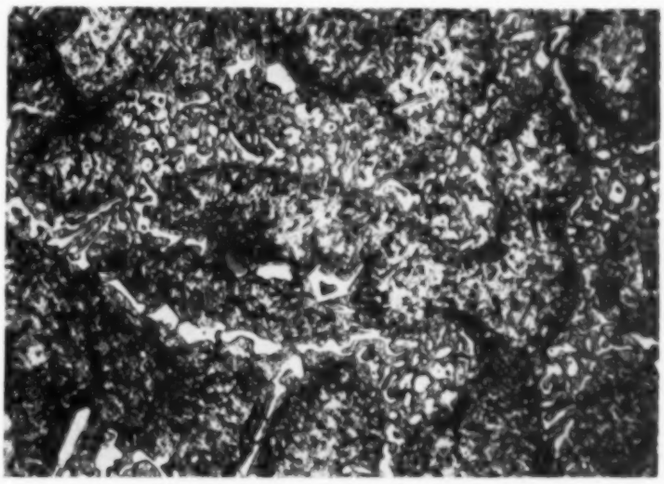
Castings in this range, melted in the electric furnace, are usually susceptible to heat treatment. They can be softened by annealing, and can be rehardened by an air quench from 1750 F. However, the susceptibility to heat treatment depends upon the amount of carbon and silicon present; the chromium-carbon ratio should be at least ten to one, and the silicon content should be less than 2%. If the silicon is much above 2%, it interferes with heat treatment, and also slightly increases the as-cast hardness.

Chromium 22 to 34%

Although most castings containing chromium from 22% to 34% with carbon from 1% to 2% have been used for resistance to abrasion and oxidation, they are also used for resistance to corrosion. It was mentioned in the preceding section that castings in the 12 to 20% range have very definite resistance to corrosion. This resistance is, of course, greatly enhanced as the chromium is increased. Castings containing 24% to 28% chromium are highly resistant to certain types of corrosion, while castings containing over 32% approach stainlessness, as was pointed out by Houdremont and Wasmuht in *Metals and Alloys*, February 1933. A good deal of new information on the high chromium, high

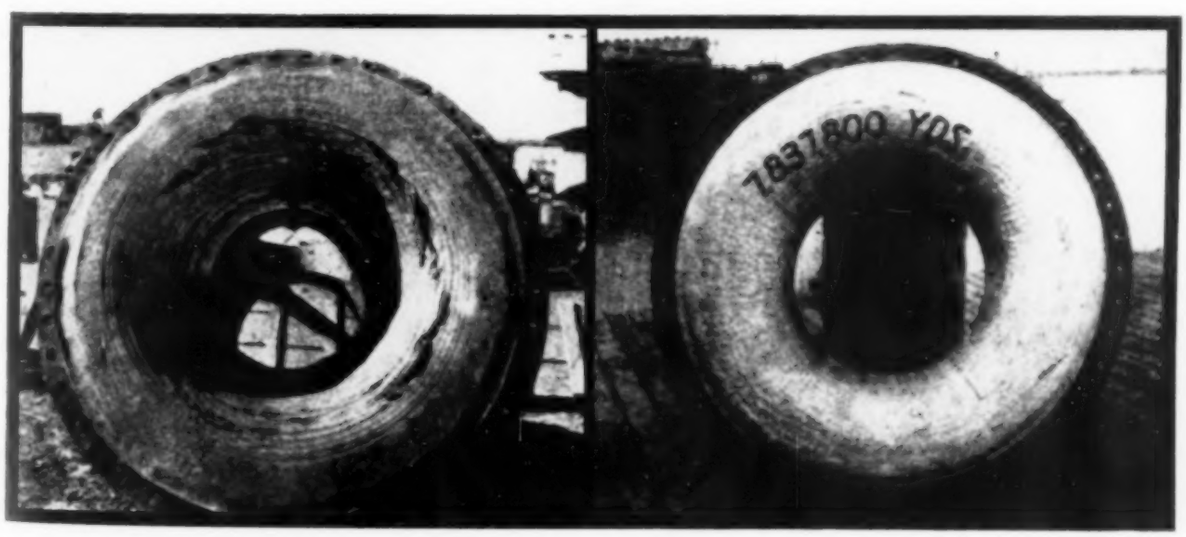
One of the most widely used compositions in this range is 24% chromium with rather low carbon (between 1.25 and 1.90%, according to machinability requirements). With 1.25 to 1.90% carbon, such castings may show 450 Brinell as cast, but can be heat treated for machinability by annealing for 8 hr. at 1650° F., cooling with the furnace to 1100° F. and then air quenching (the Brinell thus being reduced to about 320). They can then be reharden-ed, if desired, by air quenching from 1750° F., producing about 600 Brinell.

Because of its high carbon content, 24% chromium cast iron is easy to pour, and accordingly is used for all sizes of castings. It gives very good service in applications where abrasion, oxidation, and corrosion are all present at high temperatures, such as are encountered in cement mills. The microstructure shown in the last view is that of a 24% chromium, 1.50% carbon iron giving very satisfactory service under severe abrasive conditions.



Microstructure of Iron With 24% Chromium, 1.50% Carbon. Brinell hardness number 578. Etched, 500×

For extreme resistance to abrasion, the composition 28% chromium, 2.00 to 2.60% carbon is effective. Such castings are particularly useful when scoured by sand and similar abrasives. Where service conditions demand great resistance to impact, the various high chromium or chromium-nickel, low carbon steels are more satisfactory.



Front Head Liners of Sand Pumps on Government Dredge. Left, stock liner after 1,470,500 cu.yd.; right, high chromium cast iron liner after 7,837,800 cu.yd.

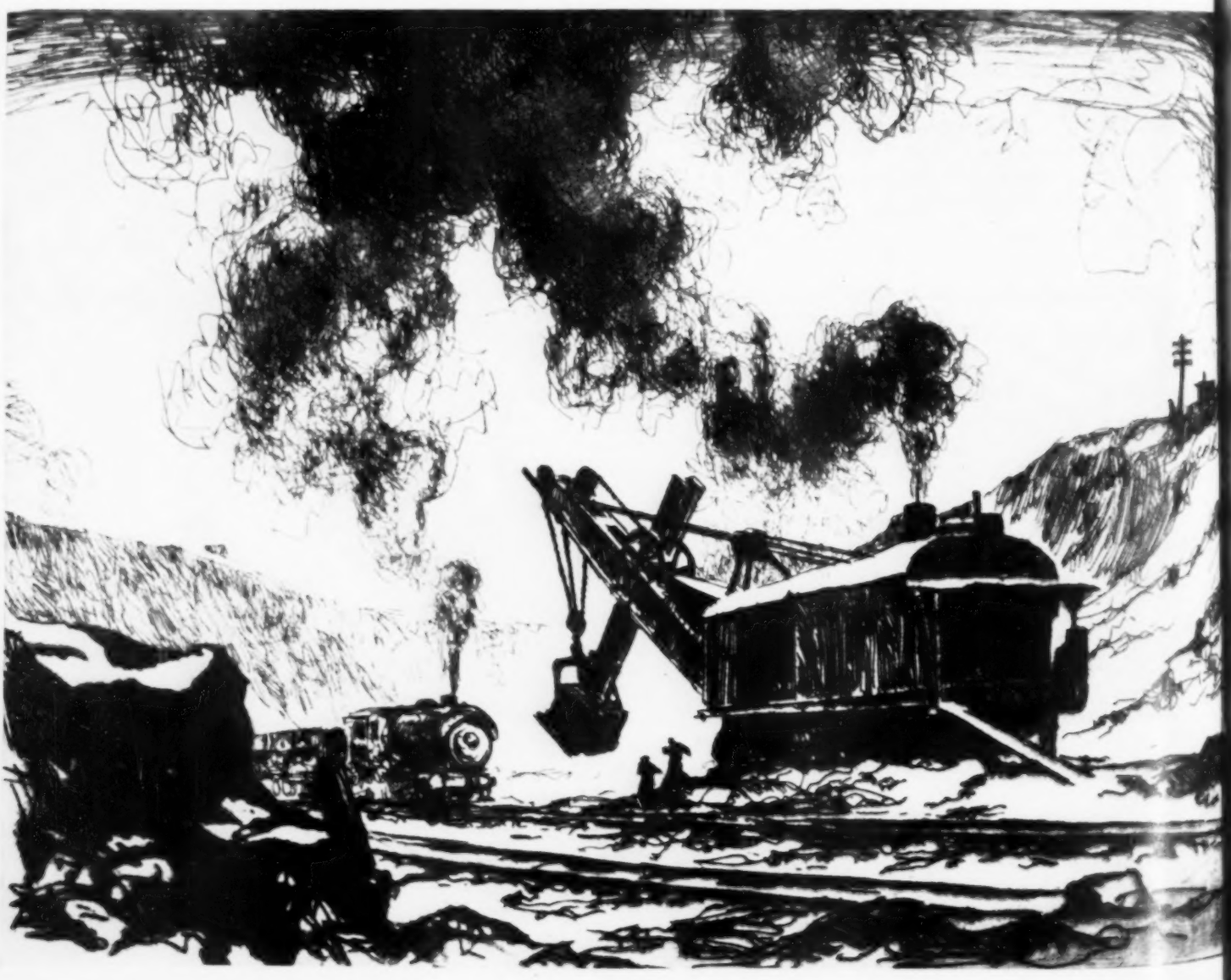
carbon castings is contained in the article by John Sissener in METAL PROGRESS for October 1937. Interesting data on the physical properties are given by Garnett Phillips, in the A.F.A. *Transactions* for 1934.

Two practical service reports of recent date are pertinent. The first extract is taken from a report on the use of high chromium, high carbon castings for liners in crushing equipment:

"The chromium-iron castings showed practically no wear at the time the carbon steel castings were worn out and taken out of service. It was estimated that the chromium-iron castings would last at least three times as long as the steel castings. It was found that the life of carbon steel liner plates was from four to ten weeks, whereas the life of the chromium-iron plates was from one to four years, depending on their location and the amount of material that passed over them. The life of the chromium-iron was, therefore, 13 to 21 times that of carbon steel, depending on the amount of service."

An illustration is given of a recent installation described in *Engineering News-Record* for December 2, 1937, in an article entitled "Longer Life for Dredge Pumps" by T. B. Jefferson. Government engineers, constructing a large dam, conducted "further experiments to obtain more resistant front and back head liners for use with the rubber shoulders in suction dredges. Finally, a chromium cast iron alloy was adopted for this use. This material, as-cast, has a Brinell hardness of about 600 and a tensile strength of over 50,000 psi. Due to the high physical properties of this metal, the liners are hard enough to resist the most abrasive action likely to be imposed while pumping sand-water mixtures. Also they have enough tensile strength to withstand the shocks and severe impact to which they are subjected while pumping gravel and glacial boulders. Comparative views of old and new front head liners are shown; the initial liner wore out under 1,470,500 cu.yd. of pumping. Note how the liner has worn to such an extent that even the front head has been damaged, requiring repairs. The chromium cast iron front head liner, after handling 7,837,800 cu.yd., is still usable."

From an Etching "The Big Shovel" by Otto Kuhler.



Metallurgy at Buick

organization, gas carburizing, hardening of malleable

SINCE DETROIT was host to the ⚙ convention last month, and many of those who attended had an opportunity of inspecting new metallurgical operations in the automotive plants thereabouts, it is opportune to give some of the high spots in the Buick motor division of General Motors Corp. located at Flint — perhaps far enough from Campus Martius to discourage a personal visit of inspection.

First it is desirable to say something about the general setup for metallurgical control — the all-important problem of men and organization. Then will be outlined some of the newer metallurgical advances that have been achieved at Buick through the unique coordination of metallurgical research and control coupled with a comprehensive supervision of production techniques and equipment. The staff is fortunate also in securing an entirely new and enlarged metallurgical and chemical laboratory — an essential production tool, these days — but this will be no more than mentioned at this moment.

Organization

Chief objectives of the heat treating department are consumer acceptance through rigid and comprehensive quality control, and an unceasing program of improvement and cost reduction through the adoption of better or more suitable materials and metallurgical methods.

It is of interest to note that to achieve these objectives production heat treating at Buick is entirely under the direction of the metallurgical division. The production facilities are decentralized in the interest of better economy and closer control, and are divided into four major units. Thus, there will be found a completely self-contained heat treating department in the transmission plant, in the motor building, in the differential department, and in conjunction with the forge shop.

Intimate contact is maintained with each of these departments through a staff of four metallurgical "lab contact men", each of these having responsibility for one of the four heat treating units. Duties of the contact man are to cooperate with the foreman of his department, to supervise the operation of all equipment, to assume responsibility for quality control, and to shoot trouble. While this is by no means a complete catalogue of all his duties, it constitutes the most important.

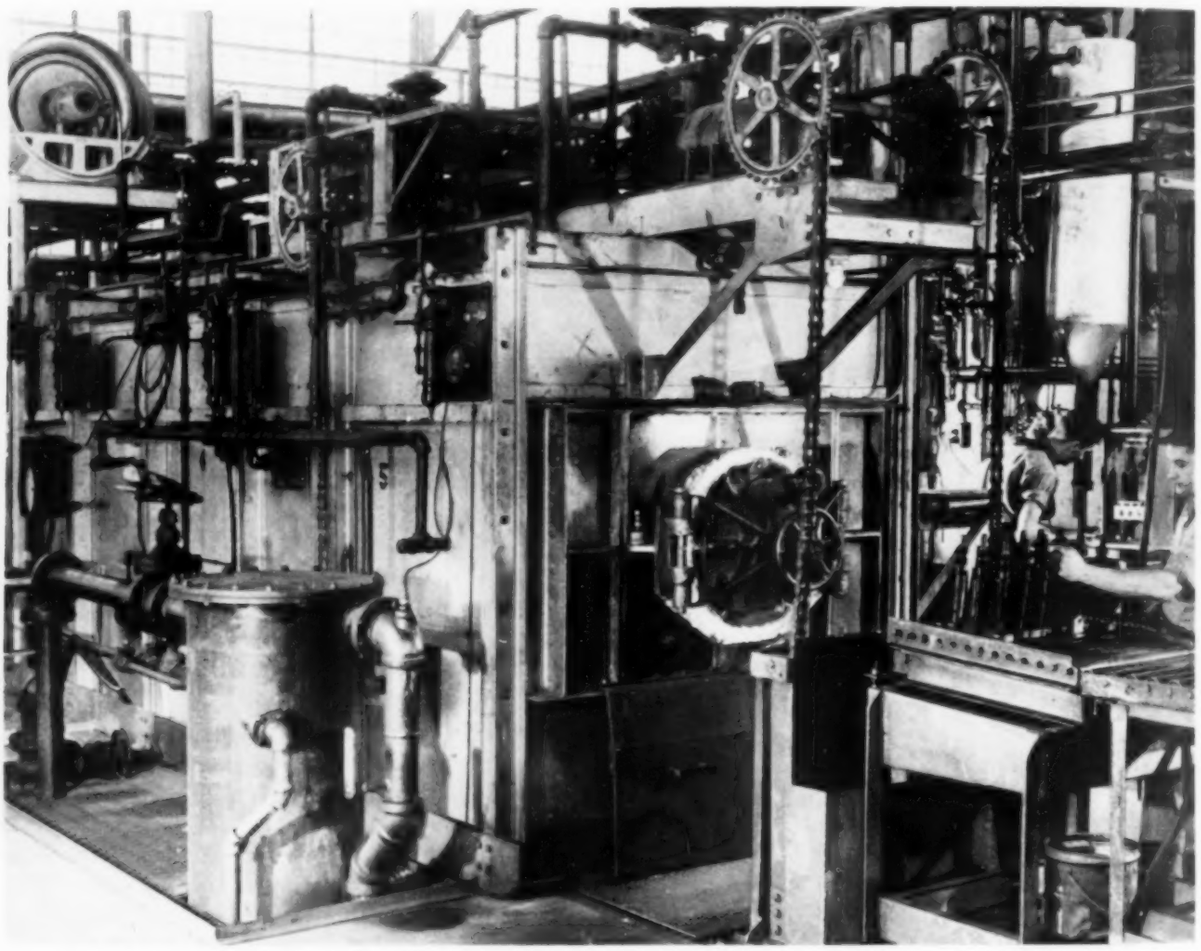
To facilitate and assure quality control of production, each of these staff metallurgists supervises a group of special inspectors, responsible to him alone, whose function it is to check work in process as well as the finished product before it is permitted to leave the department. The degree of quality control is specified on the standards established by the laboratory. By the same token, the size of the inspection group depends entirely upon the volume of production in each department.

In addition to being supervised by the contact metallurgists, the pyrometer equipment throughout the plant is made the responsibility of the furnace engineer, attached to the metallurgical laboratory, who is in general charge of

the pyrometer department. Personnel in this department maintains constant contact with all equipment in the plant, attends to the calibration of pyrometers, and has complete facilities for its maintenance and repair. This setup assures the accuracy of the measuring devices so essential to the maintenance of quality. It may also be noted that all of the production heat treating equipment is fitted with the most modern instrumentation and automatic temperature controls of various types.

carburizing unit several years ago, new and improved units have been added, and early in 1938 Buick discontinued this particular cyaniding operation, accepting the gas carburizing method as standard practice in the hardening of all transmission gears.

Meanwhile in the never ending search for improved procedures, it was discovered that the gas carburizing furnace could be used for the surface treatment of a variety of miscellaneous parts heretofore surface hardened by liquid



Continuous Gas Carburizing Furnace for Hardening Transmission Gears. A case 0.006 in. deep is produced in 88 min. at 1510° F., quenched and drawn at 450° F. to C-50 to C-56 tooth hardness

Improved Gas Carburization

Previous technical papers relative to Buick's heat treating methods have shown that this organization was probably the first to experiment with gas carburizing for the heat treatment of high carbon transmission gears, heretofore almost exclusively quenched from cyanide baths. Since the introduction of the first gas cyaniding. This procedure has been adopted as standard in 1939 production, marking, it is believed, one of the first large scale applications of this process for the production of light cases. The new Buick procedure will be described more in detail presently.

With this brief glimpse at the background, some details of the treatment of a number of representative parts are in order. Before giving

these details, it may be noted that the heat treatment of every individual part processed in each department is covered by standard specifications issued by the metallurgical laboratory. The foreman of each department is provided with these instructions in the form of a work sheet which lists every part going through his department and gives complete details of every phase of the treatment and quality standard.

Countershaft Gear — As a representative example of the heat treatment of transmission gears may be selected the countershaft gear. It is made from selected hot rolled bars, G.M.C. specification 3145-A, $1\frac{9}{16}$ in. diameter, having the following chemical specifications:

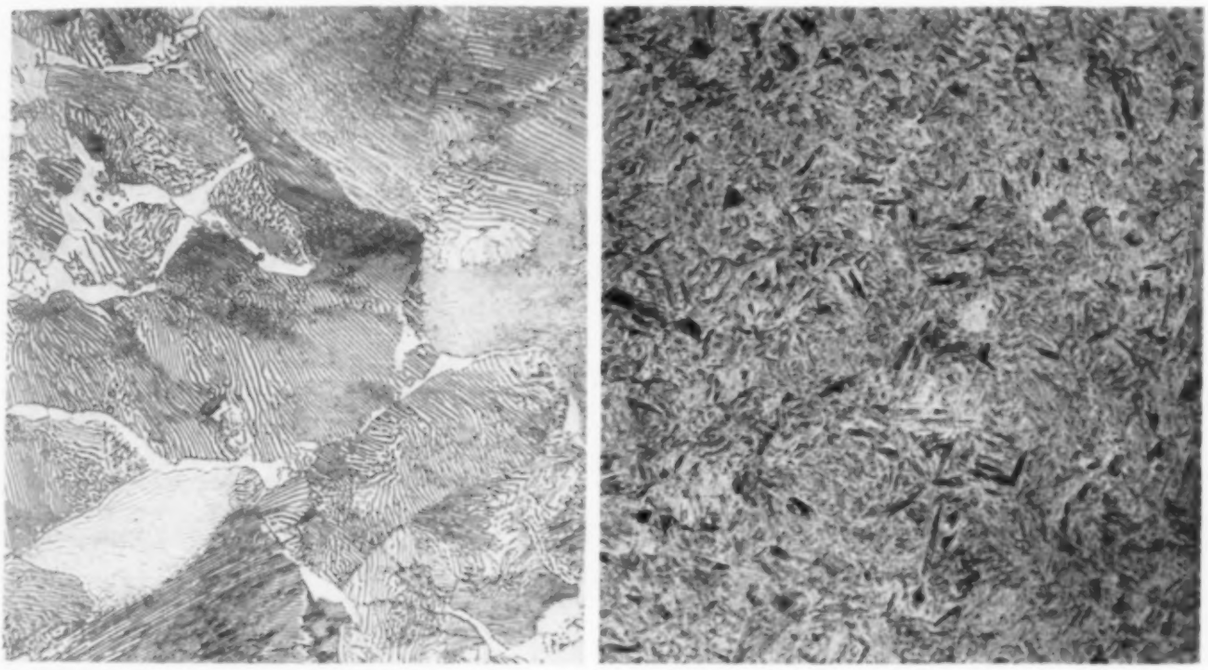
Carbon	0.43 to 0.48%
Manganese	0.60 to 0.90%
Phosphorus	0.040% max.
Sulphur	0.050% max.
Nickel	1.00 to 1.50%
Chromium	0.45 to 0.75%
Grain size	6 to 8

The forging is upset, then annealed at 1575° F. to a Brinell hardness of 187 to 207. It is then ready for machining, which is done in the transmission department.

After machining, the gears are routed to the heat treating department in this building. All parts are loaded in the controlled atmosphere furnace illustrated on page 570, heated at 1510° F., using about 730 cu.ft. of prepared gas per hr. The gears are held in the furnace for 88 min., this treatment producing a case about 0.006 in. deep.

Gears then are quenched directly in oil without exposure to outside air and tempered at 450° F., producing a Rockwell hardness of C-50 to C-56 on the gear teeth. Microstructures of the annealed forging and the hardened and drawn gear are shown at 750 diameters magnification in the views below.

Light Cases — As mentioned earlier, it is thought that the most dramatic advance has been made in the surface hardening of parts heretofore treated in the liquid cyanide bath. In Buick production there are a variety of parts which require a file hard surface with depth of case varying from 0.002 to 0.010 in. depending upon operating conditions.



Structure of Annealed Gear Forging of G.M.C. 3145-A Steel (Oil Quenching Nickel-Chromium) and of the Core After Hardening and Drawing. Both 750 ×

A group of parts which require a 0.002-in. depth of case is represented by such items as *(a)* forward and reverse shifter shaft, S.A.E. 1020 steel machined forging; *(b)* knuckle spindle nut, S.A.E. 1112 steel automatic machined part. Representative of parts requiring a depth of case of 0.007 in. are *(a)* valve adjusting ball studs and *(b)* valve push rod uppers, both automatic machined parts made of S.A.E. 1112 steel. Finally there is a group requiring a 0.010-in.

case, of which the oil pump shafts and oil pump idler gear pins are typical; these parts also are machined from S.A.E. 1112 steel.

To obtain a case with file hard surface, the parts are heated in the controlled atmosphere furnace using a special ammonia gas mixture consisting of 730 cu.ft. of carburizing gas, and 130 cu.ft. of ammonia gas. This results in a total gas volume of 860 cu.ft. of mixture per hour. Work is held in the furnace for the required length of time at a temperature of 1525° F., then quenched in oil. A case depth of 0.010 in., file hard, can be obtained in about 2 hr. 15 min.

Hardened Malleable Iron

Perhaps one of the most interesting of the metallurgical developments for which Buick has been responsible this season is the treatment of the new valve rocker arm. This part, formerly a drop forging, is a pearlitic malleable iron casting made by General Motors' malleable foundry in Saginaw, Mich. As received, the casting has a Brinell hardness of 156 to 197 and is machined in this condition.

To produce the desired surface hardness at the valve end, so essential to wear resistance at this point, the machined castings are heat treated at the valve end only, by dipping in liquid lead at 1575° F. for 15 min. and quenching in water. The entire casting then is tempered at 400° F. The valve end must be file hard after this treatment. A macro at four diameters is shown below of a cross section of this piece after the heat treatment described.

Valve Rocker Arm — a Pearlitic Malleable Iron Hardened File Hard on the End by Dipping 15 Min. in Lead at 1575° F. and Drawing at 400° F. Section magnified 4 ×

Oxy-Acetylene Welding

By C. F. Keel

Abstract of Translation by F. Eder of article in *Zeitschrift für Schweisstechnik*, V. 27, p. 168

RECENT studies by Séférian in France indicate that the "neutral" welding flame produces a temperature of about 5700° F. (3100 to 3200° C.) ½ in. from the tip of the blowpipe, and the gases at that place analyze 61% CO, 22% molecular hydrogen and 17% atomic hydrogen. These gases are highly reducing, and therefore any iron oxide existing or appearing will be reduced to metal. Other alloying metals in the puddle are lost by secondary actions around the focus of the flame. In welding rods containing 0.15 to 0.30% carbon, about half of the carbon is lost in the process — a fact difficult to explain. (Evaporation has been suggested, since the sublimation temperature of carbon has been quoted as 3700° C.)

It is known that welding is speeded if the flame is "oxidizing". A 25% excess of oxygen is not objectionable if welding rods with extra manganese and silicon are used, which oxidize preferentially to the iron. In our own researches in Switzerland we have obtained a new welding rod containing aluminum which makes very good seams with 10 to 25% excess oxygen in the welding flame. Its analysis is approximately 0.27% C, 0.80% Mn, 0.25% Si, and 0.20% Al. Carbon and manganese are of primary importance for strength and should be retained in the joint. Silicon and aluminum are protective elements and are deoxidizers; some disappears during welding.

Welded joints can also have their carbon preserved, or even increased, by use of a "carburizing" flame (excess of acetylene), and only small losses are experienced in the silicon and manganese content. This practice is useful for welding medium carbon steel which later is to be heat treated, and for building up wear-resisting surfaces. All such hard welds should be subsequently annealed.

The present trend is to utilize rods of higher strength. It is desirable to achieve this by other means than by increasing the carbon, and alternative methods are well known to the art of formulating high strength, low alloy steels. Most European welding rods of this sort follow the early American example of using 0.25% or more silicon, and 0.75% or more manganese. A Swiss rod of this general type contains 0.15% C, 0.80% Si, 0.70% Mn and 0.45% Cr. A French rod has 0.20 C, 0.35 Si, 0.70 Mn and 3.5% Ni. A German example is 0.15 C, 0.40 Si, 1.00 Mn, 0.30 Cu, 0.10 Cr, and 0.65 Ni. A Belgian rod is about the same without the chromium and nickel. It is not suggested that these are equivalent in properties, merely that they indicate the trend toward high strength oxy-acetylene welding technique in Europe.

By Edwin C. Wright
Metallurgist, National Tube Co.
and H. Habart
Metallurgist, Ellwood Works
National Tube Co.

typical failures of Still Tubes in refineries (a -- carbon steel tubes)

CRACKING STILL TUBES have been used for approximately 20 years. The first cracking coils using high pressure were constructed by C. P. Dubbs during the War. Originally, cold drawn carbon steel tubes were used exclusively, but these have been largely displaced during the last 10 years by a variety of alloy steel tubes of which there are now at least 20 different types. The National Tube Co. made the first cracking still tubes and has been intimately connected with the industry ever since. During this period, hundreds of ruptured still tubes have been examined in our laboratories, and these failures discussed with refinery engineers. This paper, to be published in two parts, consists largely of a summary of the many metallurgical autopsies which have been performed in that time, wherein it was found that the failures fall into definite classes.

The earliest investigations were on tube specimens which had burst wide open for a considerable distance. These failures often occurred after only a few hundred hours of service (as compared to a life of several thousand hours which is now expected). The only material then in use was low carbon boiler tube steel, and the required sizes were usually estimated from the properties of the steel at room temperature. As no boilers had then been built for temperatures above 600° F., the design of equipment for 850° F. and higher was very largely guesswork. Little or nothing was known of the strength of materials at high temperature, and the characteristic of flow or creep of hot metal had hardly been recognized. As a result, tubes were put into operation under conditions far beyond their capacity; they burst wide open when failure occurred.

Typical examples of the type of rupture which was early encountered are shown in the first cut (page 574). One had been in service for only 12 days and had apparently been overheated throughout its brief service life. Examination of this type of fracture invariably discloses microstructures similar to those observed in tensile test pieces broken on short time at high temperature. Sections cut from the metal adjacent to the rupture invariably show directional flow lines of work, and it is believed that this kind of failure is practically the same thing as the short time, high temperature bursting test. A tube will ordinarily expand approximately 25% of its diameter before failing in a bursting test, and the order of expansion on this kind of failure is similar.

It is interesting to note that rupturing of tubes in cracking coils in this manner has disappeared during the last five or ten years.

In the early days, the requirements of tubes for cracking coils had not been clearly defined, and occasional tubes definitely defective were encountered. A short section of a tube containing rolling mill laps, which were the cause of the rupture, is shown in the center of Fig. 1. These overfills or laps are produced in rolling seamless tubes when the pierced billet,

First Portion of a Paper Read Before the 1938 Western Metal Congress

Fig. 1 — Left: Carbon steel Tube Which Failed in 12 Days, Apparently Overheated Throughout Its Brief Service Life. Right: Such early failures due to overheating are not now encountered. Metal adjacent to fracture has same flow lines in microstructure as metal in a short time, high temperature, tensile test. Center: Laps or mill defects cannot slip by the rigid inspection now given furnace tubes

entering the rolling mill, is too large in diameter for the rolling mill groove; under these conditions the metal shears in the pass or laps over. Such a defect offers a path for oxidation by the furnace gases, which gradually deepens with service and finally develops into a notch, which accelerates failure. A tube with such a defect may often fail with little expansion. This condition is now extremely rare, due to the fact that all furnace tubes receive such careful inspection at the plants when they are made.

Another type of failure, which seems to be largely mechanical or operational, is readily described. We have in mind an original 5-in. o.d. tube which had expanded in a series of bulges along a length of 6 ft. Although this one did not open up, it was very near the rupture point at one position, where the outside diameter was 5.722 in. This condition can be developed either by creep in long time service or by severe turbining of the tubes, after shutdown, but while the tubes are too hot. Defects of this sort were actually produced at one refinery where tubes were heated to different temperatures and then turbined. It was found that above 600° F. the turbining caused localized bulging, particularly when the turbining tool was left in one position for too long a time.

Serious cases of overheating of the metal are even yet evident in carbon steel tubes withdrawn from service, although this factor also is decreasing from better control of furnace operation. Figure 2 shows the metal structure adjacent to the rupture of a tube which was heated to a very high temperature. The coarse austenitic grain size of this metal is readily apparent; it would be estimated as grain size No. 1 by the standard American Society for Testing Materials' chart. This may be compared with grain size No. 8, the structure of the metal at a point 180° around the tube from the rupture, typical of the fine grain metal

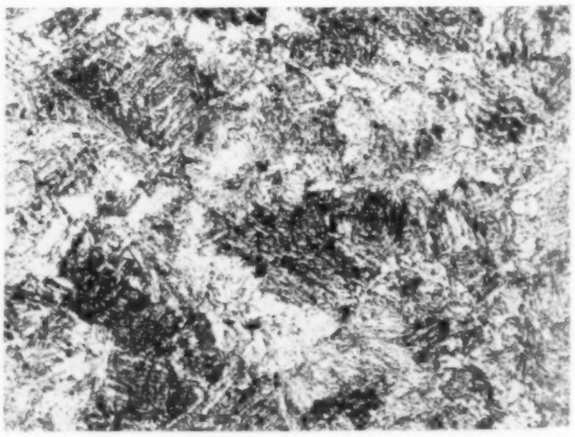


Fig. 2 — Microstructure of Overheated Tube. Coarse austenitic grain is in sharp contrast with ferrite of grain size No. 8 in same tube 180° from point of rupture. All micros etched with 2% HNO_3 in alcohol: 100 ×

of the original tube which has undergone little transformation. The investigator never knows whether the structure exhibited in Fig. 2 represents that of the tube before rupture or whether it was developed from overheating from the fires which usually result when a still tube blows out. Figure 3 shows several failed tubes whose structure was found to be overheated, together with evidences of severe flow or work of the metal adjacent to the point of rupture or maximum bulge.

During the past two or three years there has been considerable discussion of a possibility of failure of metals at high temperatures through intercrystalline cracking, due either to oxidation or corrosion of grain boundaries. In all of these studies of ours, extending over 20 years, only one instance of this type of failure has been encountered in steels of the ferritic type used in stills for cracking petroleum. (This ferritic type includes all of the low carbon, carbon-molybdenum, and alloy steels containing 1 to 5% chromium.) It may probably be significant that this one case observed represents a carbon steel tube taken from a refinery in West Texas which had been processing an extremely corrosive high sulphur crude. The inside surface of this tube was honeycombed with intergranular fissures as shown in Fig. 4 (page 576). Examination of the metal close to the cracks under the microscope exhibited typical structures associated with intergranular corrosion as shown in Fig. 5, taken at 1000 diameters. Such intergranular corrosion on the inside of a ferritic steel tube has never been encountered before by us except where hydrogen gas was present in considerable volume, as in equipment for ammonia synthesis.

Two investigations reported during the past year have raised considerable anxiety among engineers regarding the intergranular failure of ferritic steels when under stress at high temperatures. This appears unwarranted for, as stated above, in all of our studies of boiler tubes, superheater tubes, cracking still tubes, and tubes in high pressure chemical plant service, instances of intergranular failure of ferritic steels have been extremely rare except in the presence of hydrogen gas. In view of this comprehensive experience it is surprising to read in a paper before the International Association for Testing Materials in April, 1937, entitled "Creep and Engineering Design" by R. W. Bailey: "Appreciable weakening of the steel may occur in time, and evi-

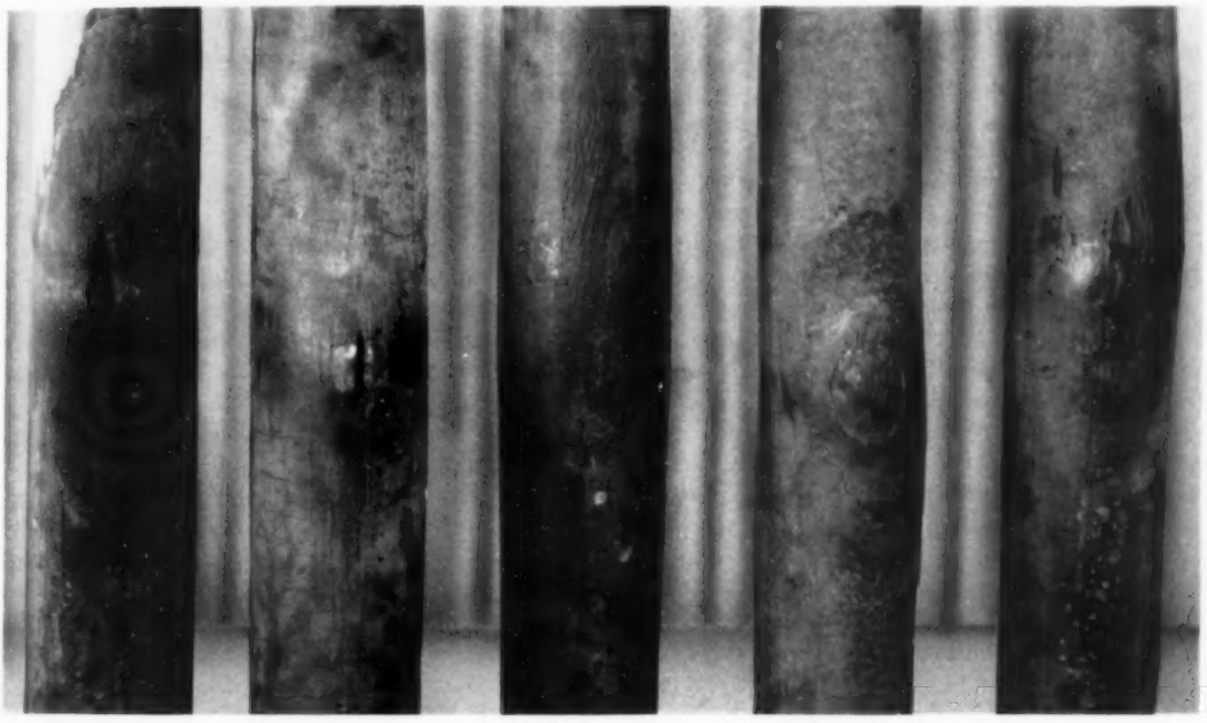


Fig. 3—Carbon Steel Tubes Whose Microstructure Indicates Severe Overheating

dence shows that probably all low alloy, high creep-resistant steels fail under creep conditions by intercrystalline cracking with comparatively low ductility." He further stated, " . . . . total creep should not exceed 0.005 strain for high creep-resistant steels containing molybdenum."

These remarks were apparently based not upon service at all, but on creep-to-fracture tests made at 1020° F. at the British National Physical Laboratory. The steel was a carbon-molybdenum steel and the stresses employed were 20,000 to 34,000 psi., a range above that normally used for this steel even in creep testing, and far above the stresses in equipment properly designed to work at this temperature. When tested at these high stresses at 1020° F., the specimens showed early intergranular failure with comparatively low ductility. The corresponding creep rates were abnormally high (20% to 4000% per 10,000 hr.). One would scarcely expect such investigations to yield knowledge of value in design.

Papers by Clark & White and by White, Clark & Wilson published in *Transactions* ASME, 1936 and 1937 respectively, present similar examples of intergranular failure in ferritic steels. In the first mentioned, a sample of S.A.E. 1015 steel tested at 1000° F. at stresses of 12,000, 9000 and 6000 psi. exhibited intercrystalline fractures in periods of 1552 hr., 4788.5 hr., and 13,950.75 hr. respectively. The creep limit for this steel for reasonable design purposes at 1000° F. is about 3000 psi. for 1% elongation in 10,000 hr. (0.1% per 1000 hr. or 0.0001% per hr.). The loads described in these papers are respectively four, three, and two times this figure. In the case of the 6000-psi. stress, the specimen apparently behaved normally for some 10,000 hr., after which the rate of straining or creep increased enormously. Similar cases of intergranular failure were reported in the second mentioned paper on "The Rupture Strength of Steels" by Messrs. White, Clark & Wilson, where the rate of straining was well above that observed in ordinary creep tests.

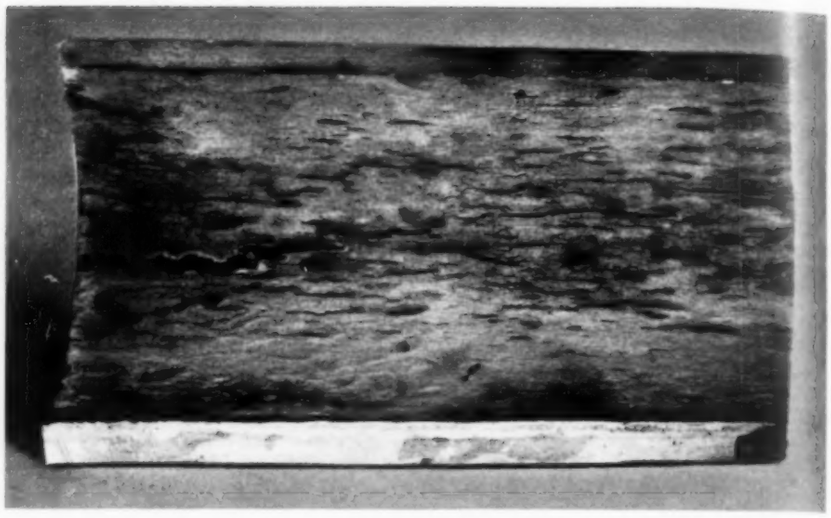


Fig. 4 — Sole Example of Intergranular Corrosion of Carbon Steel Refinery Tubes Encountered in 20 Years' Experience. This tube handled extremely corrosive, high sulphur, West Texas crude

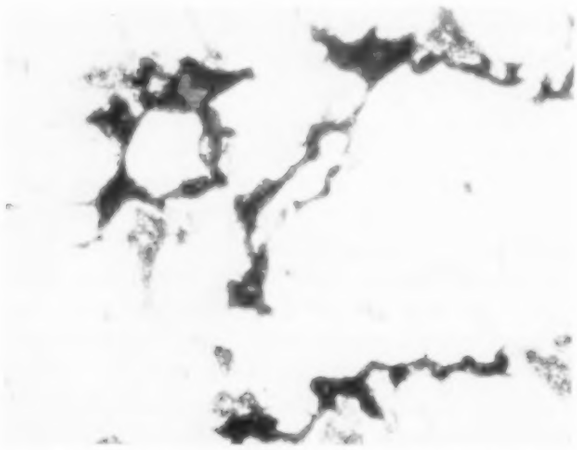
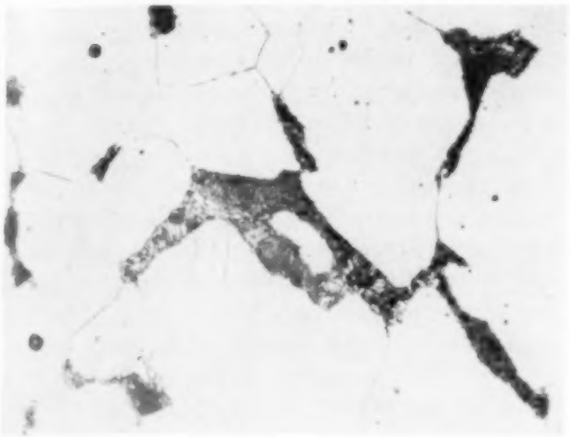


Fig. 5 — Intergranular Corrosion in Metal of Fig. 4, Near a Crack. Magnification 1000 ×

It is quite significant that these intercrystalline failures are almost never encountered in ruptured still tubes, even after periods of 30,000 hr. It is also reported that intercrystalline failure does not occur in creep tests where the stress or rate of straining is near the limiting creep load as usually defined (1% in 10,000 hr.). There are no known instances where tubes have been designed to operate at stresses high enough to produce intercrystalline fracture. Even in severe cases of overheating, where the operating temperature is such that rapid rates of straining should occur, the tubes do not fail except by a normal transcrystalline fracture. On the other hand, the evidence that intergranular failure of ferritic steels is common at *high* stresses is of great importance, and points more emphatically

to the fact that stresses chosen for pressure tubes should be such as will produce a low rate of creep.

The foregoing examples were selected from carbon steel tubes. It will be impossible to indicate all of the microscopic changes which do occur in them under still tube operating conditions. It has become evident, however, that the original structure of carbon steel gradually and definitely changes to that of an equilibrium state, during its long exposure to high temperatures. The original structure of the tube metal is practically always that of the normalized condition (Fig. 6); the constituents are ferrite and lamellar pearlite. If the metal is held a long time at temperature, the carbides in the lamellar pearlite gradually coalesce into a massive or fine globular state as shown in Fig. 7. However, if the time at temperature is long enough, the round carbide particles coalesce into larger carbide particles. In steels low in alloys other than silicon or nickel, carbide may finally decompose into graphite, and the structure of the original low carbon steel may finally become similar to that of malleable iron containing a very small amount of carbon in the form of graphite. Figure 8 shows one of many small spots of graphite in a carbon steel tube which had been in service for approximately 6000 hr. with an observed tube metal temperature of at least 1100° F. The photomicrograph shows graphite, adjacent to undecomposed carbides, inside a ferrite grain.



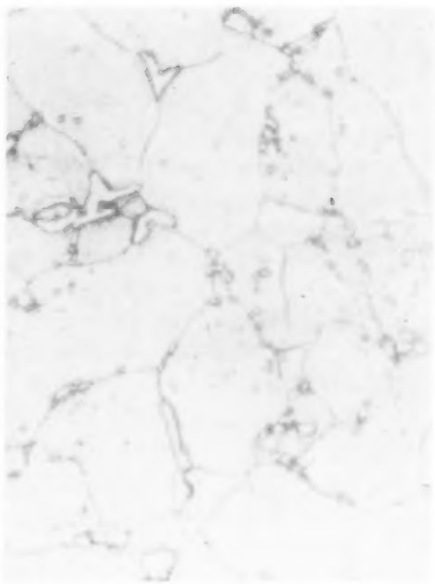


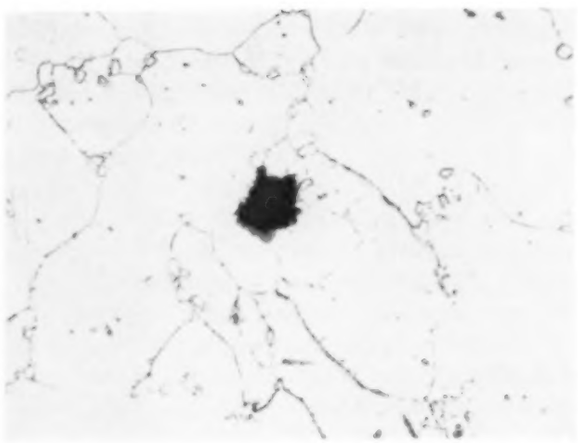
Fig. 6, 7 and 8 — Original Pearlite in Carbon Steel Tubes Changes to Spheroidized Cementite After Long Exposure at More than 1000° F., and Eventually the Cementite Will Graphitize. All micros at 500 ×

Physical properties of the metal in these conditions also undergo changes:

Condition	Yield Point	Tensile Strength	Elongation in 2 in.
Normalized	30,000 psi.	52,000 psi.	42.0%
Spheroidized	27,000	47,800	40.0
Graphitized	22,000	39,000	21.0

Low carbon steels with ½% and 1% molybdenum are also subject to carbide coalescence almost the same as that observed in plain low carbon steel although, as would be expected, graphite has never yet been encountered in the molybdenum-bearing steels. The chromium alloys, containing from 2 to 5% chromium, seem to have somewhat more stable structures, although even in these materials some coalescence and enlargement of carbide particles take place, and some softening of the metal is noted after long periods at high working temperatures.

Even more remarkable instances of this graphite formation have been reported by R. W. Moore of the general laboratories, Socony-Vacuum Oil Co. He investigated carbon steel tubes with a service life history of



20,000 to 45,000 hr. This long service for carbon steel in cracking coils is far beyond that reported by any other refinery to the writers' knowledge, as the usual life of a carbon steel tube, depending upon corrosion conditions, seems to be between 2000 and 15,000 hr. In the extremely long service life investigated by Dr. Moore, the presence of graphite was well established in a number of tubes. Sometimes different sections of the same tube, which had apparently operated with a thermal gradient, showed all degrees of spheroidization and final graphite formation. These data are interesting because they show the trend of the structural changes in the steel used for cracking stills.

The structural transformations evident in Fig. 6 to 8 require quite high temperatures, apparently at least 1000° F. Like all diffusion phenomena, the time and temperature seem to be the main controlling factors, and the effect of stress, so far as can be discovered, is somewhat negligible. Specimens of normalized steels heated to 1000° F. with or without stress change in structure very slowly, and it may take several thousand hours to spheroidize the original lamellar pearlite completely at this temperature. Diffusion, and hence coalescence, is much more rapid at 1100° F. At 1200° F. a complete change to spheroidized carbides occurs in 100 hr. without the application of any stress.

Metal Temperature Approaches 1200° F.

In practically all of the still tube failures examined, the original carbide as pearlite has been changed to the spheroidized state; the only difference between them is in the size of the carbide particles. This makes it evident that still tubes which have ruptured have been operating at metal temperatures considerably above 1000° F. In present day cracking furnaces, the optimum outlet oil temperature is 1050° F., and the metal temperature of the tube must be considerably higher than this, especially in the last row of tubes where the oil stream is hottest. If the tube has any deposit of coke, which has a high insulating effect, the metal temperature of the tube must approach 1150° to 1200° F., and at these metal temperatures the load carrying ability of the carbon steels is quite low. It is believed that tubes in the outlet section of the coil should be designed to offset this condition either by the use of heavier wall thicknesses or alloys of greater creep strength, and this feature has lately been given consideration.

Action of "Oiliness Compounds"

By Martin Seyt

It is well known that the effectiveness of an ordinary mineral oil lubricant when used under severe load conditions can be greatly increased by the addition of a very small quantity of some polar organic compound. In practice, the addition of these so-called oiliness compounds results in reduced friction and increased film strength which tends to prevent seizure. In theory, these results have been rationalized by supposing that the addition agent forms a thin film over the bearing surfaces with the active ends of the polar molecules so firmly anchored in the metal that tremendous forces are necessary to disrupt the film of lubricant.

Recently L. H. Germer and K. H. Storks of the Bell Telephone Laboratories have reported in *Journal of Chemical Physics* (Vol. 6, p. 1280, May 1938) electron diffraction experiments which not only support some of the previous lubrication theories but also furnish a new and apparently powerful technique for investigating fundamental problems of boundary lubrication.

Following a method developed by Langmuir and Blodgett of the General Electric Co., mono-molecular layers of stearic acid and of barium stearate were transferred from water surfaces to polished chromium or steel surfaces. The electron diffraction patterns show that when either of these substances is deposited in a layer one molecule thick the long molecular chains stand nearly perpendicular to the surface, like the fuzz on a peach. The carboxyl ends of the stearic acid molecules and the barium ends of the barium stearate molecules are firmly attached to the metal surface, so firmly in fact that there is no regularity in the lateral packing of the molecular chains. When more than one layer is deposited on the metal surface the molecules in each layer above the first are packed together in a regular array. Thus, while the molecules in the first layer are tightly bound to the metal surface, those in higher layers are free to take the arrangement normally found in crystals of stearic acid or barium stearate.

Although the experiments give no direct information about the nature of the bonding forces between metal and the organic molecules,

they do show that these forces do not extend appreciably beyond the first molecular layer. This result is significant. It is in line with the fact that only small amounts of a polar compound need be added to a mineral oil to produce a large increase in oiliness. Moreover it supplies an explanation for various conflicting results obtained by a number of investigators who have used electron and X-ray diffraction methods to study the molecular orientation of oils on metal surfaces. Apparently the oil films used in most of this earlier work have been much too thick to show any possible effect due to forces between metal and oil.

Germer and Storks state their intention of applying the new technique to a study of fundamental problems in boundary lubrication. The results of their work will be awaited with interest by all who concern themselves with bearings and their lubrication.

Rapid Steel Refining

By D. F. Campbell

Extracts from "Electric Furnaces in European Steelworks"; fall 1938 meeting, British Iron & Steel Institute

SEVERAL new processes or changes in metallurgical methods of arc furnace practice have been introduced in Europe in recent years, resulting in great acceleration of the reactions.

A remarkable discovery was made a few years ago — that violently oxidized metal, after the dephosphorizing slag was removed, could be reduced to a properly killed steel by rapid agitation with a suitable slag free from oxide of iron. Further, it was found that sulphur could be removed by the use of an ordinary slag of lime and iron ore if the temperature were raised and the slag contained a high percentage of lime and low silicon. [See the letter from Albert Portevin in **Metal Progress**, February 1933, on "Instantaneous Refining Reactions in Slag-Steel Emulsion," describing Perrin's tests at Aciéries Electriques d'Ugine.]

These discoveries are leading to a revolution in practice in some European works, and the time spent in finishing a steel after it is melted in an arc furnace is being reduced from hours to minutes.

How far these rapid methods of steel making may be applied without prejudice to quality is to some extent an open question, but for many steels excellent results, as regards general chemical and physical qualities, are obtained, and the steel is definitely as free of non-metallic inclusions as steel made by more orthodox methods.

The above remarks apply to the rapid method of deoxidizing steel by mixing the steel violently in a ladle with a slag containing less than 0.5% of FeO. Within 60 sec. the steel is deoxidized and the oxide of iron in the slag is increased, so that the slag must be returned to the slag furnace for reconditioning, or scrapped and a new slag used. The percentage of slag used is so small that recovery of the slag is hardly worth while.

In addition to deoxidation, important work is being done with dephosphorizing slags, especially for the duplex refining of basic bessemer steel, and the possibility of carrying out important refining operations almost instantaneously by violent mixing of slag and metal is being recognized, now that it has been well established that such treatment does not necessarily lead to any increase of the inclusions in the steel.

In addition to rapid refining by agitation with liquid slag, similar work is being done with solid slag-making materials. In duplex working, dephosphorizing is now effected by pouring the liquid metal onto suitable slag-making materials, with the result that the dephosphorizing slag can be removed in 10 min. and a complete refining operation completed in less than 1 hr. in an electric furnace, as compared with 1½ to 2 hr. which was customary for a dephosphorizing and desulphurizing operation.

Considerable effort has been made in Europe to construct induction furnaces having violent and controlled movement in the bath. Large sums of money have been spent, but in many cases without a full understanding of the metallurgical problems, and, as a result, furnaces showing most interesting electrical phenomena have been built, and abandoned because no metallurgical advantages were established.

Electrical forces can give heat and movement in a great variety of combinations, and a nice balance between these phenomena is necessary to get metallurgical results within the limits set by our inadequate knowledge about refractories.

Investigations of simultaneous motion and heat control are full of possibilities, and our new knowledge of rapid metallurgical reaction by the mechanical mixing of slag and steel, without prejudice to the inclusion characteristics of the metal, points to great possibilities of electric furnaces operating at high frequency, low frequency or dual frequencies.

A PIONEERING METALLURGIST

William Park Woodside

PRESIDENT, AMERICAN SOCIETY FOR METALS

A FEW WEEKS AGO the writer was visiting Bill Woodside when another friend dropped in with a steel problem on his mind. Bill listened patiently and then said, "Do you know, John, that same problem came up in 1905 when I was with Cadillac." Twenty-nine years after Bill joined Cadillac, C. N. Dawe, himself an old-timer, wrote in the September 1934 METAL PROGRESS, "Bill Woodside knows more about the steel problems which arose in the early days of the automobile than any man in the industry." This remark could with justice be amplified to say that Bill's knowledge of both past and present steel problems in many industries is encyclopedic, the result of an intimate association with steel which extends back to his youth.

William Park Woodside was born on March 4, 1877 in the hamlet of Tara in Ontario. Shortly afterward his family moved to Port Arthur, Ontario, where his education was completed in the common schools. There also his association with steel began. Mr. Woodside, Senior, was a blacksmith, and it was his idea that Bill should also be one — in fact, when school days were over, his career was practically settled.

Bill had other ideas. He liked steel, in fact he was intensely interested in it, but he did not care about attaching it to horses. His interest was more along the lines of forging and tool dressing. But sons in those days did not argue with parents; the most of the business was in horse shoeing, so horse shoeing it was to be. Instead Bill planned, fought and eventually won an ingenious rear guard action. The innocent accomplice in the campaign was Gray Bess, a docile old mare that a child could drive. There was never the slightest trouble with her until Bill tried to shoe her, when there was invariably plunging and rearing and verbal fireworks that never failed to draw Woodside, Senior, to the battleground. It was not that Bess did not like Bill or objected to being shod. The fuss was all caused by the quiet but firm application of the wrong end of a hammer to that part of Bess's anatomy where it would do the most good.

In any event, it was plain that Bill would never make a farrier. So he was put to doing what he had always desired to do — forging and dressing tools. After his apprenticeship was ended he went to the U. S. Casterline Co. at Pittston, Pa., to complete his education on toolsteel and its heat treatment by actual practice.

In 1902 Bill started in business as a general blacksmith in what was then a small community: Detroit. He had learned how to forge steel and had the opportunity of putting some of his tempering education to practical use. He also developed a few tempering ideas of his own. This experience convinced him that heat treating and metallurgy of alloy steel was his destiny.

Bill gave up his business in 1905 to go with the Cadillac Motor Co. After a year or so, he left that job to start selling toolsteel to the budding automotive industry for the Crucible Steel Co. of America. He stayed with Crucible for ten years, being manager of its Detroit office when he left in 1916 to become head of the Methods and Standards Dept. of the Studebaker Corp., then a leading factor in the automotive business. During the ten years he held that position he was not only very active in alloy steel development, but also trained many young men who are today the backbone of the alloy steel industry.

In 1926 he joined the Climax Molybdenum Co., and today he is vice-president in charge of research. He is also president of the Park Chemical Co. and the American Twist Drill Co., both of Detroit.

Woodside's early experience with handling steel as a blacksmith, combined with his keen observation and a more than normal share of common sense, made him valuable to all those for whom he worked. His knowledge of the practical side won the respect of the technical men with whom he came in contact. From the very beginning they came to him for advice, even as they do now.

His foresight gave him unshakeable faith in alloy steels and their future. During his climb to his present eminence he accumulated a vast store of knowledge and practical experience. Since this knowledge has always been used in the furtherance of progress and since he himself

has been responsible for so much progress, it is only natural for the American Society for Metals to honor him with its presidency.

The story of how Bill Woodside founded the Society is typical of his practical way of looking at things and of his organizing ability. While selling toolsteel he called on many technical men in the automotive industry. It was a constant source of wonder to him that Jim Jones of ABC Co. had not the slightest idea what Jack Smith, engineer for XYZ, a firm in the same field, was doing in the interest of metallurgical progress, and the practical workmen of both companies seldom knew what either Jones or Smith were doing, or why. The result was almost complete general ignorance and confusion worse confounded by much pseudo-technical hocus-pocus. Regarding this fog with the penetrating eye of common sense, Bill decided that something should be done about it. To decide with him was to act. In October 1913 he invited 18 men to join in a "metallurgical exchange", first called the Steel Treaters' Club, later the Steel Treaters' Research Club, and finally the Steel Treaters' Research Society.

The Society grew rapidly; branches were established in several cities. A Chicago group stepped out, forming an independent American Steel Treaters' Society. Later, however, both societies merged to form the well known American Society for Steel Treating. The present name, American Society for Metals, was adopted Dec. 20, 1933. In all these changes and developments, William Park Woodside continued to take an active part in society affairs, and to assist its efforts toward a more general knowledge of metallurgical developments and their practical value.

There is another activity of his that is possibly not so generally known, but has had incalculable influence. Twenty thousand men in the automotive industries can't be wrong! That is about the number of men and boys who would rather go to Bill Woodside for advice than to anyone else they can think of, with the possible exception of their fathers. His human kindness and interest in young men who are trying to get along is inexhaustible. His ability to size up a man, and the confidence that prospective employers have in his judgment have resulted in countless jobs for those who have asked his advice.

So his influence is not confined to the technical progress of metallurgy. It is felt in the even more important field of human relations.

By Thomas Swinden

Abstract of paper for North East Coast Institution of Engineers and Shipbuilders, Feb. 25, 1938

Special Steels suitable for shipbuilding

PLAIN mild steel finds a large market in marine engineering. Its most noteworthy recent development is that toughness of carbon and low alloy steel, as judged by Izod impact tests, is related to its micro-grain size. In general, this is controlled by the effectiveness of the deoxidation during the last stages of steelmaking. Mild carbon steels of fine "inherent" grain size, obtained by the use of strong deoxidizers, are also almost completely immune to strain-age embrittlement. Representative Izod tests are as follows on samples where the operations are cumulative:

Material	Normalized	Stretched 15%	Aged 30 Min. at 500° F.
Best wrought iron	60	14	7
Basic openhearth steel			
0.09% C, grain size 3	94	68	16
0.09% C, grain size 8	96	90	85

(It will be noted in passing that wrought iron is not so very high in impact value, and it is particularly susceptible to embrittlement after moderate cold work. It also work-hardens with great facility, hence the necessity for frequent annealings of iron chains.)

Use of aluminum for grain size control does not induce quench aging of low carbon steels; in fact, fine grain steel does not appreciably react in this way. Quench aging — a gain in hardness after rapid cooling — is due to gradual precipitation of carbide from solution in supersaturated ferrite. No excess of aluminum should be used when the steel is to resist creep at high temperatures, as aluminum definitely reduces creep resistance. Silicon (and more vigorously molybdenum) increases creep resistance in an important manner. *(Turn to p. 600)*

By J. B. Austin
Carney, N.J.

inclusions in steels from Ladle Linings, nozzles & stoppers

THE ANNUAL MEETING of the Refractories Division of the American Ceramic Society is, by tradition, devoted to a discussion of refractories from some consumer's point of view. In line with this policy the chief attraction at this year's meeting, which was held at Bedford Springs, a famous watering place in the Pennsylvania mountains, was a symposium* on "Steel Mill Pouring Pit Refractories". Attendance was unusually good and since no one displayed the slightest interest in the springs, or in water of any kind for that matter, it seems safe to conclude that there is at the moment a lively interest in pit problems. This conclusion is confirmed by the fact that there was a great deal of spirited discussion after each paper. It seemed to be a pleasure for the steel makers, who have to spend so much time on consumer's complaints, to assume for a bit the role of dissatisfied customer and to recite their woes to the assembled manufacturers of refractories.

The symposium* consisted of five papers to be published later by the American Ceramic Society, and all but one were presented by a steel maker. Although each of the several speakers had a different approach, there was this thread of continuity — each man eventually came to a consideration of refractories as a possible source of inclusions in the cast metal. The inclusions discussed were not those formed by reaction within the freezing metal but were the larger ones, commonly composed of aluminum silicates, which enter the mold along with the metal. (In this review the term inclusion means only non-metallic particles of this exogenous type.) Another point common to all the papers was a confession of ignorance of the exact extent to which refractories can be held responsible for the quality of the finished steel.

The first speaker, W. C. Kitto of the Pittsburgh Steel Co., talked on "Refractories for Bottom Pouring", describing in detail the practice in his plant in pouring dead killed, bottom cast, round ingots. He emphasized several factors which must be controlled if satisfactory results are to be obtained. In general, it is desirable to pour as rapidly as is possible without incurring danger of cracks, because slow pouring often introduces large inclusions. Moreover, the runners and pouring plate should be designed so that the rate of filling of each ingot is approximately the same. It is also good practice in most cases to pour at a relatively high temperature and to have the runners and plate hot when pouring begins. As Mr. Kitto was a pioneer in the use of magnesia nozzles much of the discussion centered around his experience with them. Apparently he is still convinced of their merit. He also judges the quality of firebrick solely upon the load test, a procedure which some present did not consider entirely justified.

"A Study of the Influence of Nozzles on the Pouring Rate of Alloy Steels" was then presented by E. E. Callinan and E. C. Hite of the Timken Roller Bearing Co. In this paper, as in all subsequent ones, only top pouring of ingots was considered.

The rate of pouring an ingot can influence

*From the Greek *συμπόσιον* meaning a drinking party or feast.

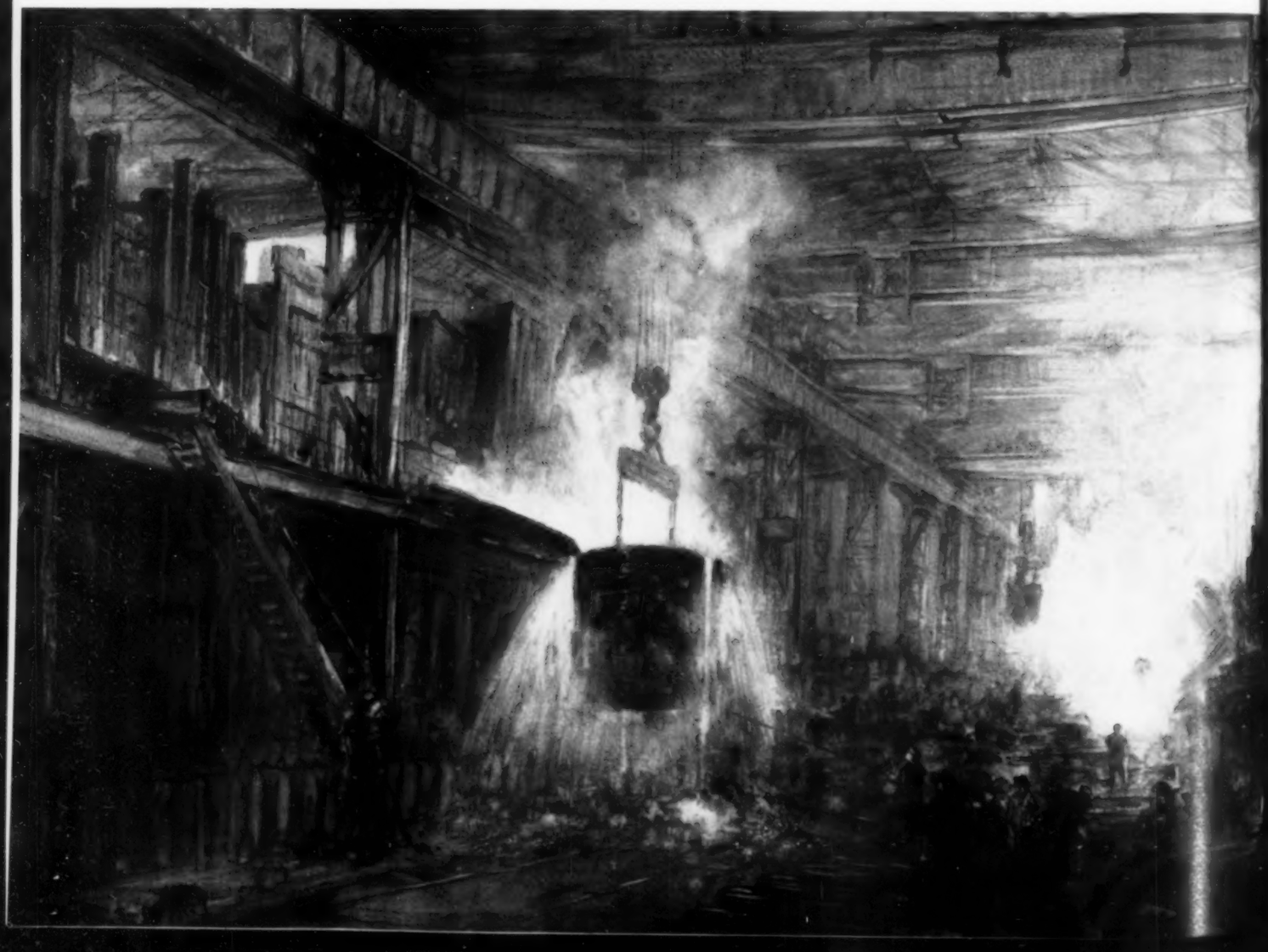
the quality of the finished steel in many ways. It may have an effect on the character of the surface of the metal, on the formation of an undesirable ingot structure, in the amount and distribution of inclusions, and on the temperature at which the last metal is teemed. It also has an effect on mold life and the amount of skull left in the ladle. In order that pouring rate may be intelligently controlled it is necessary to have a fundamental knowledge of the character of the flow of metal through the nozzle orifice and of the factors which influence this flow. To this end, a study was made of a large number of different nozzles, classified into two groups. The first and larger group was 26 nozzles selected from the common commercial grades and is designated the "common purpose" group. None had been fired to a temperature higher than cone 27 (about 2900° F.). The second group contained special or high refractory nozzles which had been fired to cone 31 (3050° F.) or higher; these were called "special purpose" nozzles. All tests were made with the nozzle fully opened.

In the common purpose group, the pouring rate increased during the first part of a pour due to the increase in orifice diameter through erosion. Toward the middle of the pour, the rate was approximately constant but toward the end, as the ferrostatic head in the ladle decreased, the rate fell off. In the special purpose group, there was little if any erosion and the pouring rate decreased steadily as the ferrostatic head diminished. Further tests showed that the pouring rate is substantially independent of the length of the orifice and that viscous flow cannot occur in a nozzle.

Messrs. Callinan and Hite assume that the best practice is to have a constant rate throughout the pour; hence they conclude that the best nozzle is the one which comes closest to maintaining a constant flow. As the shape and size of the orifice in a special purpose nozzle are likely to remain unchanged throughout the pour there is no way of compensating for the change in ferrostatic head; consequently a constant rate is hard to obtain. With general purpose nozzles, it should be possible to make a nozzle whose orifice erodes very slowly so as to compensate for the decrease in ferrostatic head and thus

Reminiscence of the Great War

From a painting by Herbert J. Finn showing the interior of openhearth shop at Messrs. Hadfields, Ltd., Sheffield, England, manufacturing steel for high explosive and armor piercing shell



give a flow which is approximately constant. If the erosion results in "stream lining" the orifice, so much the better. The porosity of the nozzle and rate of penetration of metal and slag into the refractory are additional factors influencing nozzle behavior.

In discussion some doubt was raised as to whether it has been demonstrated beyond doubt that a constant pouring rate is desirable. In reply, the authors stated that partially completed tests indicated tentatively that chipping costs may be reduced by using a constant rate.

Common Source of Inclusions

The third paper was given by D. L. McBride of the Bethlehem Steel Co., who spoke on "Pouring Pit Refractories as a Source of Non-metallic Inclusions". From a comprehensive survey of the refractories used in pouring, he pointed out how each can be a possible source of inclusions, but he also made it clear that no one now knows to what extent each actually does contribute. The first chance for erosion is in the tapping spout and although the use of a basic refractory at this point may lessen the danger it does not entirely remove it. Ladle refractories may be a more frequent source of inclusions than is commonly realized and it is interesting, although perhaps just coincidence, that the amount of non-metallic matter in the cast metal is often about the same as that eroded from the ladle lining. The stopper-rod sleeve also deserves some attention. The perfect sleeve brick has a high resistance to attack by slag and metal, has a low thermal conductivity and a high resistance to thermal shock. This is a difficult specification to meet and it is doubtful whether it is possible to meet it at all, much less economically. The nozzles themselves may cause a great deal of trouble aside from being a source of inclusions by erosion. If the nozzle does not wear evenly, the stream of molten metal splashes on the side of the mold, which causes seams in the rolled metal.

In discussion the question was raised as to whether all inclusions are harmful. Dr. McBride believes that the inclusion has been somewhat exaggerated as a cause of trouble in the finished product and pointed out that some consumers who now object to inclusions used to get along very well with wrought iron, which contained a great deal of slag. In response to a direct question he stated that in his opinion steel makers in general will not pay a higher price for special refractories as long as there are cheaper ones which do a reasonably satisfactory job. The relative merits of all-magnesia nozzles and magnesia-lined nozzles were also debated. Many of those present seemed to feel that the advantage lies with the magnesia-lined type.

"A Memoir About Steel Pouring Refractories" was presented by C. L. Kinney of the Carnegie-Illinois Steel Corp. He began by pointing out that within the past 20 years there has been relatively little improvement in either pouring pit refractories or pouring practice. In this respect pouring has lagged behind other phases of steel making. He classified the different types of inclusions found in the cast metal and showed that only certain kinds can be derived by erosion of refractories. He then questioned the common assumption that inclusions are derived *only* from the nozzle, and that material eroded from the ladle lining always rises to the top of the metal and is thus eliminated. In his opinion, bits of refractory from the bottom courses of the lining are often carried through the nozzle into the mold, and he believes that a great deal more attention should be paid to the lower part of the ladle lining. It may even prove worth while to make this section of some special refractory. His experience indicates that laboratory slagging tests are not a trustworthy criterion of performance in service. Mr. Kinney also studied the cracking of nozzles before the start of the pour and the influence of such cracks on performance. The cracks in question are usually three in number and commonly appear about 120° apart. In the discussion it was suggested that such cracks may arise from inadequate preheating, or a cooling after preheating. Mr. Kinney made a special comparison of nozzles which had been fired to a high temperature with those which had been fired to a moderate temperature, and showed that the former are not necessarily the best.

The final speaker was Walter J. Rees of the Department of Refractory Materials of University of Sheffield in England. He said that it became evident some time ago that a real advance could come about only through a cooperative effort by steel makers, refractory manufacturers and research workers, so a Joint Committee has been formed in England for a rather ambitious program to secure fundamental information. The results so far are largely tentative but a few things have been definitely shown. For example, there can be no doubt that the life of a ladle lining is prolonged

greatly if the bricks are carefully sized and shaped and carefully installed to give the most perfect finish possible. Under these conditions a practically monolithic lining is formed in service which gives very satisfactory results and more than repays the care required in its construction. Tests with a large all-basic ladle have been disappointing, but some interest has been aroused by the performance of plumbago (clay-graphite) ladle brick. Such bricks are expensive but are promising enough to warrant further trial.

Professor Rees also had a word to say about the debate on the usefulness of porosity measurements which had been running through the discussion. It had been pointed out several times that size and distribution of pores are much more significant than total pore volume, and that the permeability or ease of penetration of metal or slag into a refractory may be the factor which determines its useful life. Professor Rees was in entire agreement with this view and feels that a knowledge of permeability is more useful than a knowledge of porosity.

In conclusion, there can be no better summary of the spirit of this meeting than the closing remarks of Mr. Kinney's paper. "The problem of improving steel pouring refractories should dominantly exclude philosophical deduction and polemic dispute, because all philosophers eventually reside in Hell, since polemics, although intellectually entertaining, produce more heat than light. Although the user of refractories is in a position to supply all the heat needed, what he wants most from the ceramic world is light."

Openhearth Practice to Minimize Flakes

Abstract from *The Metallurgist*, August, 1938

SMALL internal fractures in relatively heavy forgings and rolled shapes, variously called "flakes" and "transverse fissures" are easily induced by exposing the molten steel to hydrogen, and much very recent investigation of the problem has been guided by the supposition that hydrogen in the hot steel is less and less soluble in steel at subcritical temperatures and a notable drop in the ability to *diffuse* out of the metal occurs at about 300° F. Prevention of flakes therefore involves elimination of moisture from the raw materials going into the openhearth furnace, holding ingot and bloom at a good heat until it can be given a slow cooling through the susceptible zone 600 to 400° F. at a controlled rate sufficient for the diffusion of gaseous hydrogen completely out of the given mass of solid steel. Otherwise the trapped hydrogen will build up centers of high pressure relieved only by actual bursting of the warm steel. Once this hydrogen is *out* of the metal, the heavy piece may presumably be heated in normal furnace atmospheres (or special ones relatively free of hydrogen), cooled or quenched at reasonable rates without becoming flaky.

Since the flames in an openhearth furnace contain plenty of water vapor (possibly somewhat dissociated) as products of combusion of various fuel hydrocarbons, it is conceivable that steel may absorb nascent hydrogen from this source, especially during melt-down. There are, therefore, those who believe that furnace practice has much to do with susceptibility of steel to flakes. For instance, recent work in Russia by A. F. Myrzymow (reviewed in *The Metallurgist* for August 1938) analyzes the records of about 2000 basic electric heats of S.A.E. 52100 steel for ball bearings. "Susceptibility" of each heat was measured by examining six test specimens; if none showed flakes the rating was zero, if two showed flakes the rating was two, and so on. In this way a statistical analysis could be made of the effect of several variables in the steelmaking practice on susceptibility toward flakiness.

About one fifth of the heats were all-scrap heats and of these 26% were flaky (rating 1 or more). Four fifths were scrap-and-pig heats, and only 19% of them were flaky. Minimum susceptibility to flakes in all heats was reached when the boil was 50 to 60 min. and 0.50% or more carbon eliminated. (Longer times were not necessarily associated with greater removal of carbon, but more often due to some irregular melting or furnace trouble.) Prolongation of the refining time in every case led to a susceptibility to flakes — a fact ascribed to absorption of gas from newly formed slag and added ferrosilicon, during a time when practically no degassing of the metal occurs.

Metallographic studies attempted to correlate flake susceptibility with non-metallic inclusions, with the conclusion that melting to minimize flakes also tends to produce a clean steel.

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Color Codes for Marking Metals and Alloys

Steels from Bureau of Standards' Simplified Practice Recommendation R166-37 — *Non-Ferrous Metals from Federal Standard Stock Catalogue*

S.A.E. Number	Code Color
	Carbon Steels
1010	White
1015	do
X1015	do
1020	Brown
X1020	do
1025	Red
X1025	do
1030	Blue
1035	do
1040	Green
X1040	do
1045	Orange
X1045	do
1050	Bronze
1095	Aluminum
	Free Cutting Steels
1112	Yellow
X1112	do
1120	Yellow and brown
X1314	Yellow and blue
X1315	Yellow and red
X1335	Yellow and black
X1340	do
	Manganese Steels
T1330	Orange and green
T1335	do
T1340	do
T1345	Orange and red
T1350	do
	Nickel-Chromium Steels
3115	Blue and black
3120	do
3125	Pink
3130	Blue and green
3135	do
3140	Blue and white
X3140	do
3145	do
3150	Blue and brown
3215	Blue and purple
3220	do
3230	do
3240	Blue and aluminum
3245	do
3250	Blue and bronze
3312	Orange and black
3325	do
3335	Blue and orange
3340	do
3415	Blue and pink
3435	Orange and aluminum
3450	Black and bronze

S.A.E. Number	Code Color
	Nickel Steels
2015	Red and brown
2115	Red and bronze
2315	Red and blue
2320	do
2330	Red and white
2335	do
2340	Red and green
2345	do
2350	Red and aluminum
2515	Red and black
	Molybdenum Steels
4130	Green and white
X4130	Green and bronze
4135	Green and yellow
4140	Green and brown
4150	do
4340	Green and aluminum
4345	do
4615	Green and black
4620	do
4640	Green and pink
4815	Green and purple
4820	do
	Chromium Steels
5120	Black
5140	Black and white
5150	do
52100	Black and brown
	Chromium-Vanadium Steels
6115	White and brown
6120	do
6125	White and aluminum
6130	White and yellow
6135	do
6140	White and bronze
6145	White and orange
6150	do
6195	White and purple
	Tungsten Steels
71360	Brown and orange
71660	Brown and bronze
7260	Brown and aluminum
	Silicon-Manganese Steels
9255	Bronze and aluminum
9260	do

Metal	Grade	Specifications: Federal	Specifications: Navy	Specifications: A.S.T.M.	Markings: Background	Markings: Stripe
Alclad					Lead & tan	Black
Aluminum	B	QQ-A-451	46-A-2		do	Brown
soft	A		46-A-3		do	White
half hard	B		46-A-3		do	Green
three-quarters	C		46-A-3		do	Yellow
hard	D		46-A-3		do	Red
Aluminum alloy, soft			46-A-4		Lead & red	None
half hard	B		47-A-4		do	Blue
hard	D		47-A-4		do	Brown
heat treated			47-A-3		do	Black
heat treated & rolled			47-A-3		do	White
Navy alloy A-2					Lead & white	None
do, heat treated					do	Black
Navy alloy No. 2, annealed					do	Brown
do, heat treated					do	Green
Navy alloy No. 4, soft					Lead & yellow	Blue
Brass			46-B-26		Brown & green	Black
Commercial, type 1	A	QQ-B-611		B15-18	do	Blue
do	B	QQ-B-611		B16-18	do	Lead
do	C	QQ-B-611			do	Tan
Commercial, type 2	B	QQ-B-611	47-B-2		do	Red
do	C	QQ-B-611			do	White
Naval, rolled			46-B-6		do	Yellow
Bronze	1	QQ-B-701	46-B-25		Brown & tan	Black
	2	QQ-B-701	46-B-25		do	Blue
	3	QQ-B-701	46-B-25		do	Green
	4	QQ-B-701	46-B-25		do	Lead
	5	QQ-B-701	46-B-25		do	Red
	6	QQ-B-701	46-B-25		do	White
Aluminum			46-B-19		Brown & white	Black
Journal			46-B-9		do	Blue
Manganese		QQ-B-721	46-B-16	B7-27	do	Green
Muntz Metal					do	Lead
Phosphor			46-B-14		do	Tan
Rivet					do	Red
Special					do	Yellow
Copper, hard drawn		QQ-C-501	47-C-2		Red & white	Black
Soft drawn		QQ-C-501	47-C-2		do	Blue
Phosphor	A	QQ-C-571	46-C-3		Red & yellow	Black
Silicon		QQ-C-581	46-C-2	B53-27	do	Brown
Nickel		QQ-C-541	46-M-7		do	Green
Nickel	A	QQ-N-301	46-N-2	B39-22	Green & lead	Black
	B	QQ-N-301	46-N-2	B39-22	do	Blue
Manganese-Nickel			46-N-3		Green & tan	Black
Nickel-Silver	A	QQ-N-321	46-S-3		do	Lead
Tin, phosphor		QQ-T-351	46-T-2	B51-27	Green & yellow	Black
Zinc	A	QQ-Z-351	46-Z-1		Green & white	Black
	B	QQ-Z-351	46-Z-1		do	Blue
	C	QQ-Z-351	46-Z-1		do	Brown
	D	QQ-Z-351	46-Z-1		do	Lead
	E	QQ-Z-351	46-Z-1		do	Tan

2 MILES HIGH, 2 MILES DEEP, OR IN HEAVY TRAFFIC...

YOU'RE MONEY AHEAD

BY USING

NICKEL ALLOY STEELS

BORING 2 MILES down through rock puts tremendous stresses upon oil well machinery. To shoulder such loads the Baldwin-Duckworth Chain Corp., Springfield, Mass., has developed what is said to be the strongest chain of its type ever built. With links and pins of 1.50-2.00% Nickel alloy steel, tests show a minimum ultimate strength of 185,000 lbs. Baldwin-Duckworth also builds conveyor chains from "18-8" Nickel-chromium stainless steel to resist corrosion and withstand elevated temperatures. By minimizing causes of repairs and replacements, Nickel saves you money.

GIVING WINGS to business—every plane built relies on Nickel alloy steels to assure great strength without excess weight. Wherever metals carry high loads or transmit heavy power loads, there Nickel is needed. Important also to the aircraft industry is the increasing application of corrosion resisting steels containing 8% Nickel for wings, tail assemblies, floats and other structural components which must be strong, durable, light in weight, and economical in maintenance.

LIGHTENING HAULING COSTS through Manhattan's congested traffic, a fleet of these new Gar Wood self-loading, self-dumping trucks on GMC chassis is now saving money for New York taxpayers. These lighter, stronger bodies are of Yoloy, a high tensile Nickel-copper steel produced by The Youngstown Sheet & Tube Co. In addition to high strength/weight ratio, Yoloy Nickel alloy steel provides resistance to both abrasion and corrosion. Have you asked for information about the newest uses for Nickel in your industry?

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

Letters from home and abroad

High Speed Welding

IN AN ENDEAVOR to abridge the article "High Speed Welding" by F. G. Outcalt of The Linde Air Products Co. which appeared on page 490 of the October issue of METAL PROGRESS, the Editor inadvertently modified the meaning of the original manuscript, and possibly has created some misconceptions as to technical fact. In discussing the "Unionmelt" electric welding process, the Editor used the expression "It submerges the arc. . ." This phrase was not used in the original manuscript, nor has it been used by Mr. Outcalt and his associates in their promotion of the process.

Elsewhere in the article the process is described in these words: "This new process, known as the 'Unionmelt' welding process, utilizes a bare wire electrode in combination with the special granulated 'Unionmelt' welding composition, which completely covers the end of the electrode and the edges to be welded and protects the molten weld metal from the atmosphere. . . The welding causes no smoke, light, or spatter, and the completed joint is remarkably clean and smooth, needing no chipping, peening, or wire brushing."

The latter statements, rather than the phrase inserted by the Editor, accurately describe the action which takes place in the "Unionmelt" welding process.—EDITOR.

Wanted: A Complete Marking System

ROCHESTER, N. Y.—The industrial standards group of the Rochester Industrial Management Council has had under consideration a problem that has doubtless been met by many metal working plants. It is the identification of metals for fool-proof handling in the stores and in the shop. No complete solution has yet been presented, as far as we know, and it would doubtless be well to gather information from other ASMembers as to how they are handling this problem.

At Eastman Kodak Co. it is the practice to mark our own specification number at intervals from end to end of cold finished sheet and strip (steel or non-ferrous) with a self-inking roller stamp. At the present time we are looking for a means of marking finished tubing and bar stock in a similar way with a wheel stamp.

Toolsteel bars are identified by stamping the ends with the proper Eastman Kodak specification number and in addition are painted the entire length of the bar according to a code based on past practice. The colors used are yellow, green, red, black, brown, in combination, with aluminum. The bar is painted with two stripes, the aluminum stripe indicating the steel to be toolsteel and the other color indicating the grade.

All other bars are stamped both ends with the EK specification number. When a piece is cut from stock, it is immediately marked with adhesive tape bearing the EK specification and shop order numbers. Care is always taken that the end of the stock bar carrying the specification number is placed to the back of the rack and thus identification is maintained.

It is the practice of some companies to paint the entire length of all bar stock with the exception of highly finished surfaces which are painted only at the ends.

Discussion among the Rochester group

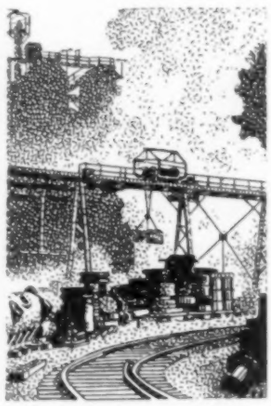
seems to favor the color system recommended by the Division of Simplified Practice, National Bureau of Standards, for identifying the S.A.E. steels. Perhaps this might be extended to include the other metals and alloys, but the chances of error in applying the correct color or recognizing it would be very great in a system as complex as this would have to be.

As far as I can discover, little or nothing has been published on this matter, and it is to be hoped that this note will stimulate correspondence from others who have devised a system which meets the needs of their own shops.

FRANCIS G. JENKINS
Material Standards Department
Eastman Kodak Company

EDITOR'S NOTE — The color code contained in Simplified Practice Recommendation R 166-37 (National Bureau of Standards, 1937) is reproduced on the data sheet in this issue of METAL PROGRESS, page 587. This code has been accepted by the National Association of Purchasing Agents, the Drop Forging Association, the U. S. War Department (in principle), and about 225 firms. It applies only to the S.A.E. steels, and even as such is not entirely complete and does not correspond to the markings in the Federal Standard Stock Catalog (Navy Department Supplement). E. V. Wills, chief cataloger for the procurement division, Treasury Dept., writes "It is understood that the code of color markings included in Federal Standard Stock Catalog is generally used by Government departments and establishments where stocks of metals are carried in sufficient quantities to occasion a need for such markings." It would appear, therefore, that practice (such as is followed) in industry is different from that in the U. S. Navy and other Government departments.

A selection of color markings applicable to non-ferrous metals, taken from the Federal Standard Stock Catalog, is also included in the data sheet, page 587. The background colors are alternated as convenient and when dry a single stripe is painted at right angles. End markings are preferred in stock ½ in. in dimension and larger. Small bars should be bundled or tagged separately with metal tags, wired on, of sufficient area for the correct identification markings.



Acid Operation of Blast Furnaces

PARIS, *France* — The new methods of operating blast furnaces with acid reactions developed in recent years by H. A. Brassert and his collaborators will undoubtedly have important economic and geographical consequences. European regions where iron manufacture by the Thomas (basic bessemer) process is practiced will be relocated, since certain ores now exploited but little or not at all may possibly be extensively utilized.

In fact, up to the present the classic method of producing Thomas iron involved the elimination of sulphur by means of a slag sufficiently high in limestone, having an index of basicity, or ratio of CaO to SiO_2, in the neighborhood of 1.5, which corresponds to a lime content of about 42 to 44%. In the east of France this is obtained by mixing two types of ores, one predominantly calcareous and the other predominantly siliceous. If the ores or ore mixtures used do not contain the desired ratio of lime to silica, limestone is added in sufficient quantity and may sometimes reach as high as 1 ton per ton of iron produced.

It is obvious that additions of this sort have the effect of considerably decreasing the actual amount of iron in the blast furnace burden and of increasing the consumption of valuable coke.

Thus a siliceous ore, such as a calcined iron carbonate ore from Normandy, containing 45% of iron and to which is added 900 kg. of lime per metric ton of iron produced, corresponds in practice to a natural ore of only 31% iron which would have the proper proportions of lime and silica. Operation on such an ore leads to a coke consumption fluctuating between 1210 and 1240 kg. per ton of iron.

On the other hand, in Brassert's new methods no effort is made to eliminate sulphur in the slag. The burden is calculated in such a way as to obtain the optimum conditions in regard to physico-thermal properties of the slag such as fusibility and fluidity, and the most economical coke consumption. This corresponds, particularly with siliceous ores, to indices of basicity decidedly lower

than 1.5 — for example, 0.9 and even less. This is what is known as "acid operation". If the ore and coke are such that the sulphur content of the resulting pig iron is too high, it is subsequently desulphurized with sodium carbonate. This entails a comparatively slight expense in view of the economies realized in the easier operation of the blast furnace.

European Iron Ores, Classified as to Increasing Basicity

Analysis	Northamptonshire (Corby)	Normandy	Salzgitter	Anjou and Britanny	Dogger
Fe	26 to 30%	45 to 46%	36%	48 to 52%	23 to 28%
SiO_2	6 to 9%	14 to 17%	20%	12 to 16%	26 to 30%
CaO	3 to 4%	3.5 to 4.5%	3.5 to 4.0%	1.5%	2.5 to 3.0%
Al_2O_3	6 to 8%	4 to 7%	7%	2 to 4%	5 to 6%
P	0.3 to 0.6%	0.6 to 0.75%	0.7 to 0.9%	0.6 to 0.7%	0.4 to 0.6%

This new blast furnace acid operation is exemplified in some important installations.

1. In England, the Corby plants use a very poor and irregular ore from Northamptonshire, never before utilized, the approximate composition of which is given in the second column in the table. They produce Thomas iron with a burden containing on the order of 30% iron (additions of mill scale and converter waste also being taken into consideration) and have a coke consumption fluctuating between 930 and 950 kg. per metric ton of iron.

These results may be attributed not only to acid operation, dispensing with calcareous additions and giving a better distribution of temperature in the various regions of the furnace, but also to careful preparation of the charge, the crushing and classification of ore and sintering of fines. In spite of the low coke consumption, the Thomas iron at Corby is made considerably hotter than those normally produced in France. This is of considerable advantage, particularly as to its conversion into steel and the eventual improvement of the steel.

2. In Germany, the Hermann Goering project provides for the construction of enormous plants in Harz, Bavaria and Austria, using lean, high silica ores from Salzgitter and Dogger. (The approximate compositions are given in the table above.)

Such a decision to embark on this large outlay in plant, taken in spite of the economic problems it raises, proves that previous trials in acid operation have given excellent results with such ores.

It is interesting to note the similarity in the gangue between the ores of western France and those of central and eastern Germany, as shown by a comparison of Normandy ores with Salzgitter ores and the ores of Anjou and Brittany with the Dogger ores. This comparison of relative proportions of SiO_2, CaO and Al_2O_3 shows that the French ores, if used in acid operation, should give more interesting results since they are much richer in iron than the corresponding German ores.

Thus, comparing figures quoted above for the classic method of working Normandy ores with results obtained at Corby, we find a saving in coke of about 300 kg. per ton of iron for blast furnaces having about the same capacity.

Finally, it may be foreseen that the regions producing Thomas iron will be relocated — that is, moved — toward the center and the east in Germany, and a possibility that French regions will be moved toward the west — a resultant widening of the joint frontier.

Albert Portevin
Bessemer Medallist

Ernesto Stassano
Pioneer Maker of Electric Steel

Turin, *Italy* — Going lately through an old number of the German review *Elektro Wärme* (Sept. 1, 1931) I read fortuitously a short article concerning Richard Lindenberg, one of the German pioneers of the manufacture of steel by the electric furnace. This article contains two statements that — as far as I know — are not completely correct. The first of them is the following: "Am 17 Februar 1906 fiel die erste Charge, so dass an diesem Tage, also zum erstem Male in der Welt, and zwar durch Richard Lindenberg, Stahl auf elektrischem Wege fabrikmässig hergestellt wurde." And the second: "So wurde bei ihm in Remscheid der erste Drehstromofen aufgestellt."

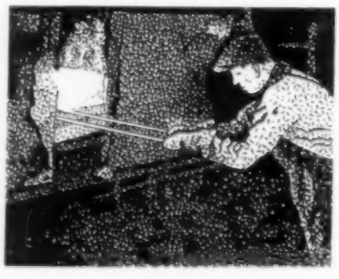
In fact, a regular and continuous production of steel, by melting and refining scrap and pig iron in three-phase electric furnaces on a real industrial scale, was started in 1902 by Ernesto Stassano at the Royal Artillery Arsenal in Turin, Italy. These furnaces continued for many years in regular production and accounted for large tonnages of steel for projectiles.

Detailed drawings of one of the furnaces are given in Dr. Haanel's "Report of the Canadian Commission Appointed to Investigate the Different Electro-Thermic Processes for the Smelting of Iron Ores and the Making of Steel in Operation in Europe". Unfortunately, the Turin furnace was down for repairs during Dr. Haanel's visit in 1904, so his commission had much less to say about the process and plant than other operating processes inspected in Sweden and France.

But already in 1898, when experimenting at Darfo with his three-phase electric shaft furnaces, intended originally for the production of steel directly from the ore, Major Stassano had made several campaigns, melting scrap and pig iron and producing large quantities of electric steel by this process. Therefore, the above-quoted statements in German — that "for the first time in the world, electric steel was produced, on an industrial scale, in a three-phase furnace by Richard Lindenberg on Feb. 17, 1906" are certainly incorrect; and it seems to me only fair to insist on the fact that Stassano was undoubtedly the first to produce electric steel on a regular industrial scale.

Ernesto Stassano was born in Southern Italy, near Naples, in 1860. When still very young, he entered the military career, and by 1896 he had become major of artillery. At that date he left active military service to devote himself to the development of electric furnaces for the reduction of iron ore. His first experiments were made near the Rome central electric station at the Ste. Maria dei Cerchi shops with a small furnace modeled after a blast furnace except that two electrodes entered the bosh where tuyeres ordinarily would be. The electrical devices were able to deliver only 130 kw. of off-peak power, which was a severe handicap. Further experiments, with larger units and a more continuous supply of current, were started the following year at Darfo, in Lombardy.

Stassano very soon discovered the inconveniences of the electric shaft-furnace when used for the reduction of ores, but at the same time he realized the great advantages that could be obtained by melting scrap in the electric furnace for the manufacture of steel.



By successive steps (as shown in his own memoir printed in the above-mentioned report by Dr. Haanel) he introduced a larger and larger constriction in the shaft above the electrode level until he had what was in effect a heating chamber and an upper charge bin. By such gradual evolution he abandoned the shaft furnace and designed a closed chamber heated by a two-phase or three-phase electric arc. After several experiments, and some alterations in the design of his new furnace, he succeeded in producing very good alloy steels from charges of about 80% scrap and 20% pig iron, and in 1898 could obtain a regular output of high quality steel on an industrial scale and at competitive costs with imported steel, using the relatively cheap power from Alpine hydro-electric plants.

The good results obtained at Darfo were still further improved by some modifications introduced by Stassano in the design of his Turin furnaces, especially in the control of the electrodes and the form and materials of the roof. The furnace installed in 1901 at the Royal Artillery Arsenal of Turin, and put in regular operation in 1902, may be therefore considered (except for a few secondary details) as the final typical Stassano furnace adopted during succeeding years in dozens of units by many European works.

In 1904 Stassano formed a company under the name of "Società Forni Termoelettrici Stassano", and erected an electric steel foundry in Turin. The new works were put in operation in 1905, and specialized on small steel castings. This foundry contained two 1-ton, two 2-ton, and one 5-ton furnaces.

In the meantime Stassano sold licenses under his patents to different Italian and foreign companies. In 1906 and 1907 several Stassano furnaces were in regular operation in Europe. Among the first to be installed may be mentioned those at Bonn (Germany) of the "Bonner Fräserfabrik" (1906-7) and the ones at St. Pölten (Austria, 1907). They were all used for the production of special steels or small and medium steel castings from scrap, rather than for the production of iron or steel direct from iron ore (as one would judge was the principal use of the Stassano furnace as described in American books on the metallurgy of steel).

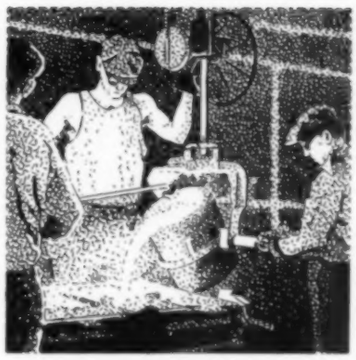
I had myself the opportunity of following very closely Stassano's

work, both at his foundry in Turin, and later when three Stassano furnaces were installed at the Ansaldo Steel Works in Genoa under my general direction, and could appreciate his perseverance, steadiness and capacity in the long and hard struggle against the great difficulties he had to overcome, especially at the beginning of his pioneer work.

Ernesto Stassano died in Naples in 1925.

He was one of the noblest characters I ever met, and during our long and intimate friendship, I always found in him the most complete unselfishness and disinterestedness. His culture was exceptionally extensive and profound, not only in technical matters, but in every field.

FEDERICO GIOLITTI
Consulting Metallurgist

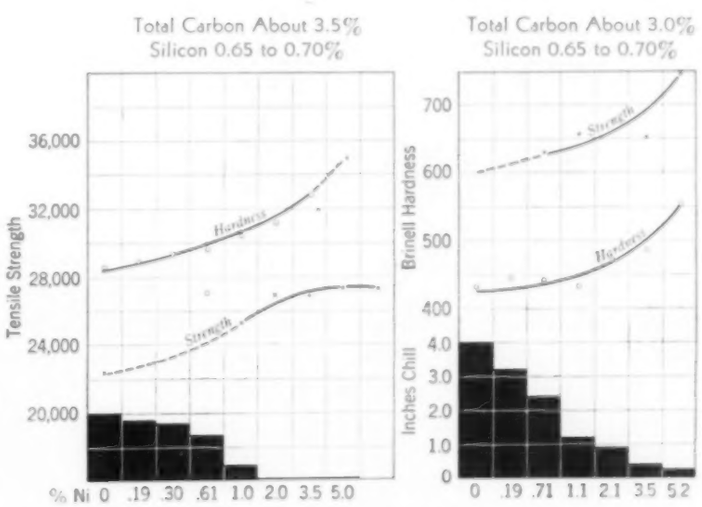


Nickel in White Cast Iron

NEW YORK, N. Y. — In the article on "Nickel-Boron Cast Iron for Resistance to Abrasion" by Walter F. Hirsch (September's METAL PROGRESS) appears a graph on page 231 whose caption reads "High Nickel Is a Softener in Cast Iron". This description seems to me to be incorrect in its major premise. In view of the statement I have frequently made in addresses before chapters and in print that high nickel is a hardener in white cast iron some explanation would appear to be necessary.

According to the Cast Metals Handbook of the American Foundrymen's Association "a white iron is a cast iron in which practically all of the carbon is in the combined form" as iron carbide, and it might be added, a cast iron with a white fracture. A portion of this iron carbide would be in the form of pearlite for the composition described by Mr. Hirsch. When nickel is added in increasing amounts to a pearlitic structure the pearlite changes gradually to sorbite and finally martensite, hardening the body progressively as it does so. If no graphite forms and the iron remains a white iron the hardness curves register an increasing hardness, as pointed out in the accompanying charts taken from a paper I presented in 1933 before the A.I.M.M.E. To obtain a measure of the hardness in this case it was necessary to chill-cast to obtain a white iron surface, and as the depth of chill decreased with increasing nickel content it was necessary to measure the Brinell hardness in a manner that would avoid breaking through the surface skin of white iron. Behind the thin white iron skin the casting was gray and soft. In the presence of a powerful carbide forming element, such as boron, obviously no graphitization occurs and the effect of nickel in hardening this material would be expected to follow the course illustrated in the curve in Mr. Hirsch's diagram marked "Effect of Nickel on White Iron with 1% Boron". His lower curve marked "Effect of Nickel on White Iron" would follow a path paralleling the boron iron curve provided the iron in question was kept white.

If rapid cooling or some carbide stabilizing element is absent then the effect of nickel additions to a white iron base composition takes the course shown by Mr. Hirsch in his lower curve, but the iron so treated is no longer white. His text explains that this curve illustrates the effect of making successive additions of nickel to an iron which was initially white. This curve might, therefore, be more properly labelled "Effect of Successive Nickel Additions to an



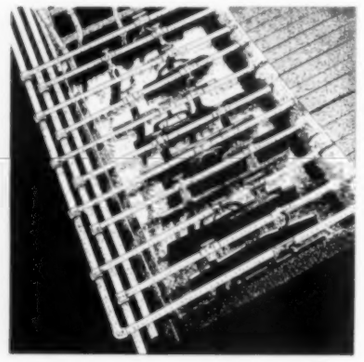
Effect of Nickel Alone Upon Hardness of Chilled Face, Strength of Gray Core, and Depth of Clear White Iron Chill

Initially White Iron Base". If this is done the hardness values would appear to be correct.

If nickel is added to a cast iron that remains white the pearlitic portion of its structure would progress toward martensite, and metallurgists will agree that no softening can occur. What obviously happened to the material represented in the chart was that the white iron became mottled and lost some hardness but at the same time lost its status as a white cast iron. Sufficient graphite had populated the body to cause it to fail to meet the definition of a white cast iron. The text of the article mentions the increasing amount of graphitization accompanying the drop in hardness, but does not commit the error made in the caption of the chart [which the Editor wrote, and he therefore stands corrected].

This criticism is not intended to discredit the good work done by Mr. Hirsch and recorded in his article. It is an effort, however, to make its presentation more accurate, so that the terms we use more clearly define and specify the materials we endeavor to describe. Otherwise, readers may find that the case is strangely similar to the plight of the shirt-shopper who insisted upon buying a white shirt and specified that it be pure white but with little black polka dots all over it!

J. S. VANICK
Development and Research Division
International Nickel Co.



First Commercial 99.99 Zinc

NEW YORK, N. Y. — Reference is made to the editorial appearing in the September issue, in which there is pointed out the advances that have occurred in the die casting industry due to the introduction of 99.99% zinc. It might have been added with truth that this grade of zinc was developed and first produced in commercial quantities in 1928 by the Sullivan Mining Co.; it has, since that time, been marketing it under the brand "Bunker Hill zinc". The advantages of this high purity metal over the old "high grade zinc" were first demonstrated by the research sponsored by the Committee on Die Castings of the American Society for Testing Materials. This committee tested 21 alloys, of which more than half were zinc base. The result of the program so demonstrated the advantages of the four-nines metal that the only zinc alloy that survived as an A.S.T.M. specification was Alloy 21 made with Bunker Hill zinc as a base.

That the industry appreciated the value of the metal of this purity can be seen from the statistics on consumption of slab zinc in the United States. Since the introduction of four-nines by the Sullivan Mining Co., the use of zinc for die casting has increased nearly 400%.

C. R. INCE
Assistant Sales Manager
St. Joseph Lead Co.

Constituents of Steel

BERKELEY, *Calif.* — Although I have no desire to become involved in a long discussion on nomenclature, I find it impossible to refrain from replying to Professor Sauveur's comments in METAL PROGRESS, September 1938, on my previously published article.

Difficulty "to conceive of a solid solution" of carbon in martensite, without experimental proof, cannot be considered a very strong argument that martensite is not such a solid solution. There is good evidence, however, that martensite has a tetragonal form which does not etch readily with alkaline sodium picrate. Since carbides etch darkly with this reagent, proof is offered that they are not present (or present to a very limited extent) and, therefore, they must be in solution. Inasmuch as heating martensite slightly produces a darker etching material, evidence is presented that martensite is an unstable solid solution or a supersaturated solid solution. A body-centered cubic form of martensite is also known for which similar etching characteristics have been established.

Of course, direct information concerning the exact location of the carbon atoms has not yet been presented, but this point is of minor significance in the present discussion. Epstein defines martensite as a "hard, brittle constituent" that "consists of tetragonal or cubic body-

centered iron with carbon in supersaturated solution". (Note the use of the word "solution".) This definition appears to me to be scientifically correct and useful.

I am fairly well convinced that no one knows why martensite is hard. Attributing the hardness to a "critical size" is a conjecture (and not proof). I believe that most metallurgists are agreed that the "critical size" theory may account for a small part of the hardness of martensite. Since unbiased facts are not available, metallurgists have hesitated to become opinionated as to how small this part may be. Obviously it is not the entire story of the hardness of martensite, and any inference that this theory is included in a definition of martensite should be avoided.

I have no objections to Professor Sauveur's definition of pearlite as a definition, but I seriously doubt whether he will have frequent occasion to use the term if he applies it rigorously. A 0.90% carbon steel is not eutectoidal, and, as a matter of fact, the eutectoid composition of steels varies depending upon the other elements present. Furthermore slowly cooled steels do not always form a lamellar structure; if cooled infinitely slowly coalesced carbides and even graphite may form; if rate retarding elements are present, martensite may result or austenite may be retained. It is practically impossible to consider chemical composition, rates of cooling, the phase diagram, or the stability of the phases in a satisfactory and useful definition of pearlite. Personally, I find the definition based solely on what is seen under the microscope broad enough to be applied and sufficiently precise to be useful. I doubt, however, whether I have ever seen Professor Sauveur's pearlite.

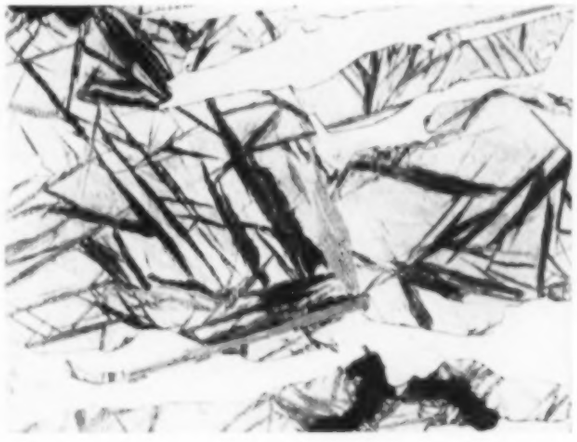
I wish to take this opportunity to correct an error which appeared in the table "Constituents of Steel" in METAL PROGRESS last August. Mr. Vilella kindly brought to my attention the fact that throughout the table the term "picral" should be replaced by "alkaline sodium picrate". My sincere thanks to Mr. Vilella and my apologies to the Editor.

JOHN E. DORN
Asst. Prof. of Mechanical Engineering
University of California

Bainite in Chill-Cast Alloy Rolls

VANDERGRIFT, *Pa.* — Because "bainite" is the product of the isothermal decomposition of austenite at temperatures below the maximum rate on the S curve, many metallurgists are apt to regard the micro-constituent as a metallographic rarity. This is not entirely the case, for there are many tons of this structure turning over at the command of unsuspecting bainite users throughout the country.

The accompanying micrograph at 500× was taken at our Canton Plant laboratory from a 3.00% carbon, 5.00% nickel grain type roll such as used for work rolls in the four-high, continuous, hot strip mills. The feathery structure especially well shown at the very center of the micrograph corresponds closely to Vilella's illustrations of bainite in R. F. Mehl's recent paper on the "Physics of Hardenability". The



rest of the structure consists of eutectic carbide, graphite and an austenitic ground mass.

These rolls are cast against chills and so present from the surface to the center a continuous series of hardened microstructures ranging from austenite plus martensite at the surface through bainite to nodular troostite and finally ending as lamellar pearlite deep in the interior portions. The structure illustrated was found 0.8 to 1.0 in. below the cast surface.

F. H. ALLISON, JR.
Metallurgist, Vandergrift Plant
United Engineering & Foundry Co.

Personals

Transferred from Buffalo by Bliss & Laughlin, Inc.: **Clyde Llewelyn**, to take charge of sales and engineering in the Hartford, Boston, New York and Philadelphia territories.

W. A. Chapman has recently been appointed manager of laboratories for Robert W. Hunt Co.

William K. Kellogg has been transferred from the Chicago office of Crucible Steel Co. of America to the Sanderson Works in Syracuse to gain mill experience.

William A. Kimsey, formerly chief engineer for LeBlond Aircraft Engine Corp., has been made chief engineer for newly organized Ken-Royce Aircraft Engine Co., Kansas City, Mo.

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T. D. Cartledge, formerly assistant general sales manager, has been appointed general sales manager of The Linde Air Products Co.

A. J. Legault, sales engineer in charge of the Montreal office of the Bristol Co. of Canada, Ltd., has been transferred to the head office in Toronto as sales manager in charge of Canadian business.

Robert F. Kimber has accepted a position at Mechanics Institute, Rochester, N. Y., teaching a class in hardening and tempering of toolsteel.

Zay Jeffries, past president, has been elected a member of the corporation of Case School of Applied Science, Cleveland, where he taught for several years.

Made sales engineer for Ohio Steel Foundry Co. covering Pennsylvania and West Virginia: **W. F. Bender**, formerly with General Alloys Co.

Robert C. Pultz is now metallurgical inspector with Jones and Laughlin at Aliquippa, Pa.

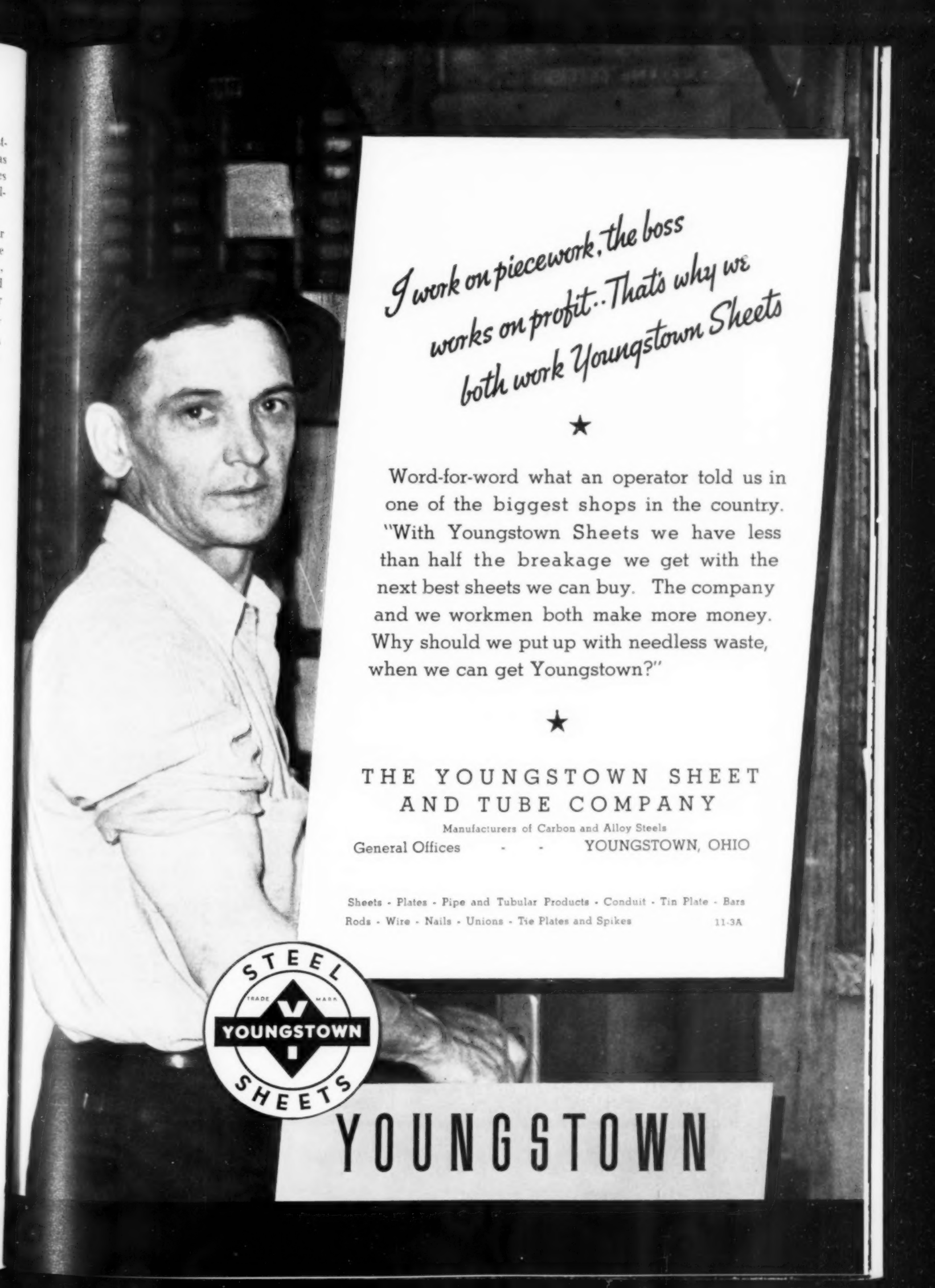
J. A. Mathews, Jr. has left Crucible Steel Co. of America and is now with Egleston Bros. & Co. of Long Island City, New York agents for Bethlehem toolsteels.

Appointed by Continental Roll & Steel Foundry Co.: **deWitt H. Gunsolus** as representative for the furnace division with offices in Cincinnati.

John R. Johnston, manager of sales, Milwaukee district sales office of Carnegie-Illinois Steel Corp., has been appointed assistant manager of sales, Chicago district sales office.

Richard A. Wilde has been appointed special research graduate assistant in mining and metallurgical engineering in the Engineering Experiment Station, University of Illinois.

Chester T. Hammond has been made president and treasurer of Niagara Rug & Carpet Co., Inc., Buffalo, N.Y.


I work on piecework, the boss works on profit..That's why we both work Youngstown Sheets
★
Word-for-word what an operator told us in one of the biggest shops in the country. "With Youngstown Sheets we have less than half the breakage we get with the next best sheets we can buy. The company and we workmen both make more money. Why should we put up with needless waste, when we can get Youngstown?"
★
THE YOUNGSTOWN SHEET AND TUBE COMPANY
Manufacturers of Carbon and Alloy Steels
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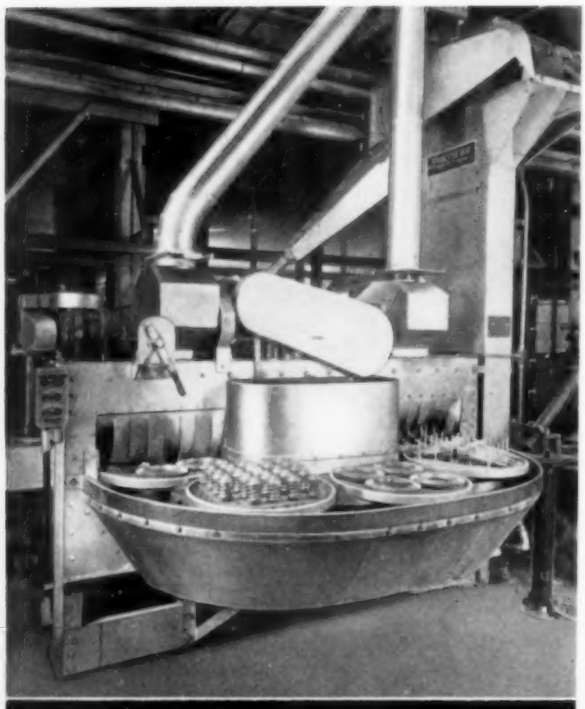

IMPROVED MACHINABILITY
AND LONGER TOOL LIFE
ACHIEVED BY
WHEELABRATING

If you produce castings, forgings, or heat-treated products for your own plant use you can obtain additional profits in final processing by cleaning them in the Wheelabrator.

And if you produce for others you will have a much easier selling job if you supply Wheelabrated products because this airless metal cleaning process provides:

1. A perfectly clean, sand and scale-free surface that improves machinability and increases tool life.
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Let us tell you of the many other profit-making advantages of Wheelabrating. There is no obligation, of course. Write today.

The AMERICAN
FOUNDRY EQUIPMENT CO.
511 S. BYRKIT ST., MISHAWAKA, IND.

Ship steels

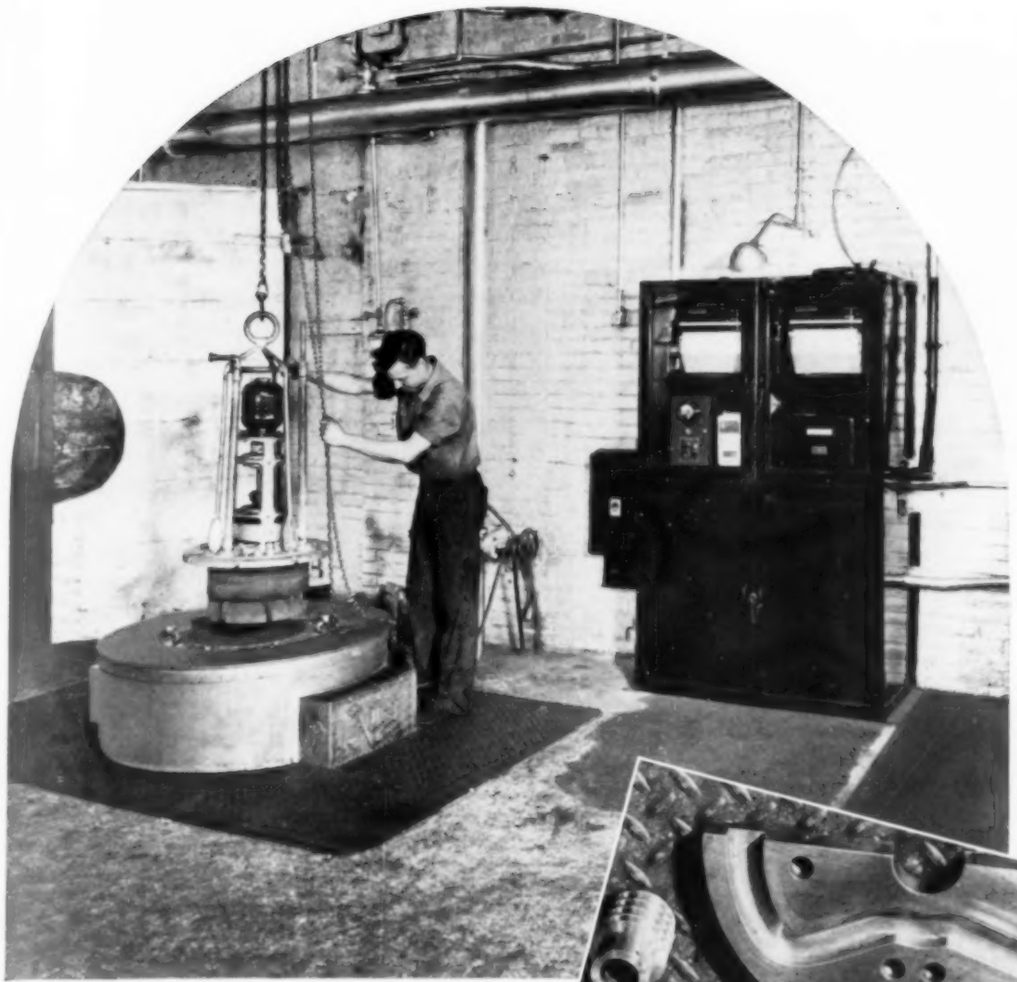
(Continued from page 582)

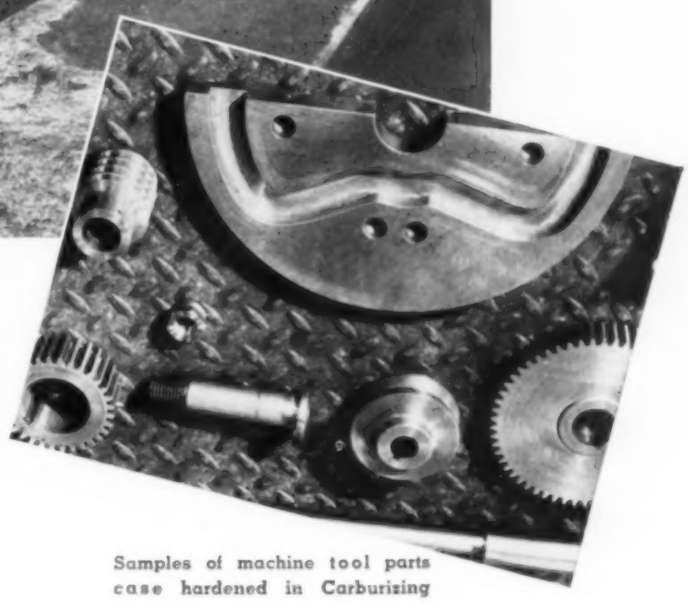
Corrosion is most important to marine structures. Tests and opinions concerning mild steel of various qualities are contradictory. However, a recent summary of all the experience available to Lloyd's Register may be summed up as disposing finally of the suggestion that post-War steel is inferior to pre-War steel. There is little definite evidence that copper-bearing steel is superior in resistance to sea water. Conditions of exposure are generally more influential in determining the corrosion rate than the steel's chemical or metallurgical condition; hence adequate protection is still of paramount importance.

One is constrained to ask whether there *is* any serious problem today in the welding of mild steel, as far as the nature of the base metal is concerned. In steels of the somewhat higher tensile strengths (around 90,000 psi.) the hardened zone behind the weld is often cracked. This is most easily controlled by using a steel which is strengthened by alloying the ferrite rather than by using extra carbon or carbide forming alloys, and by introducing an element such as titanium to inhibit hardening by the carbon which is normally present. Such a steel is C 0.15, Mn 1.44, Si 0.16, Cu 0.20, Ti 0.37. Its ultimate is 85,000 psi., yield 67,000 psi., elongation 20% in 8 in., and reduction of area 60% (abbreviated to 85,000; 67,000; 20 in 8 in.; 60). As a metallurgical development, I would say that alloys of the inhibitor class represent one of the striking discoveries of recent years.

For steels of extra strength, full use should first be made of the cheap alloying elements manganese, silicon and copper. Chromium is also useful, but not essential. Silicon, used for the first extra-strength structural steel, is least effective; it was therefore a very normal development to increase the manganese to about 1.40% with carbon 0.22 to 0.24%. This gives the well-known "Admiralty D steel". Half a per cent of copper further improves it. Its manufacture and manipulation is a straightforward proposition. Representative tensile tests would show 86,000; 53,500; 25 in 8 in.; 50; and elastic limit of 47,000 psi.

All these figures can be increased by one tenth in a fine-grained steel similar to the last mentioned wherein the *(Continued on page 602)*





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To insure reliable operation over long periods of time, the Cleveland Automatic Machine Co. carburize many of their important screw machine parts in a Hevi Duty Vertical Retort Carburizer. Uniformity from heat to heat, high quality of case and economy of operation help them to produce better quality machine tools.

Samples of machine tool parts case hardened in Carburizing Furnace.

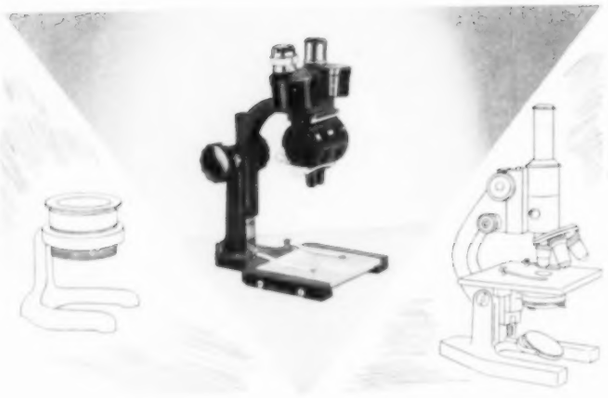
Send for Bulletin HD 937. It describes the Vertical Retort Carburizer.

HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES HEVI DUTY ELECTRIC EXCLUSIVELY

TRADE MARK REGISTERED U. S. PAT. OFFICE

MILWAUKEE, WISCONSIN



THREE DIMENSIONAL MICROSCOPY

● Filling a Gap in Industrial Examination and Inspection

B & L AKW Wide Field Binocular Microscope. May be placed directly upon the specimen, or in the case of smaller specimens the clear glass stage (shown) 100 x 100 mm. may be used. Patented Drum Nosepiece permits rapid change of magnification without refocusing.

THE B & L Wide Field Binocular Microscope fills the gap between the simple magnifying glass and the high power microscope. With magnifications from 7 to 150 diameters it covers the range of greatest usefulness in observation and inspection.

The stereoscopic picture it affords in which the image appears exactly as the eyes would see it, erect and unreversed, adds to its value in this work. Other outstanding features include an extremely wide field, long working distance that leaves ample room for manipulation of specimens, high eyepoint and instantaneous change from one magnification to another with Parfocal Objectives.

For complete information write for B & L Catalog D-15. Bausch & Lomb Optical Co., 638 St. Paul St., Rochester, N. Y.

BAUSCH & LOMB

....WE MAKE OUR OWN GLASS TO INSURE STANDARDIZED PRODUCTION

FOR YOUR GLASSES INSIST ON B&L ORTHOGON LENSES AND B&L FRAMES....

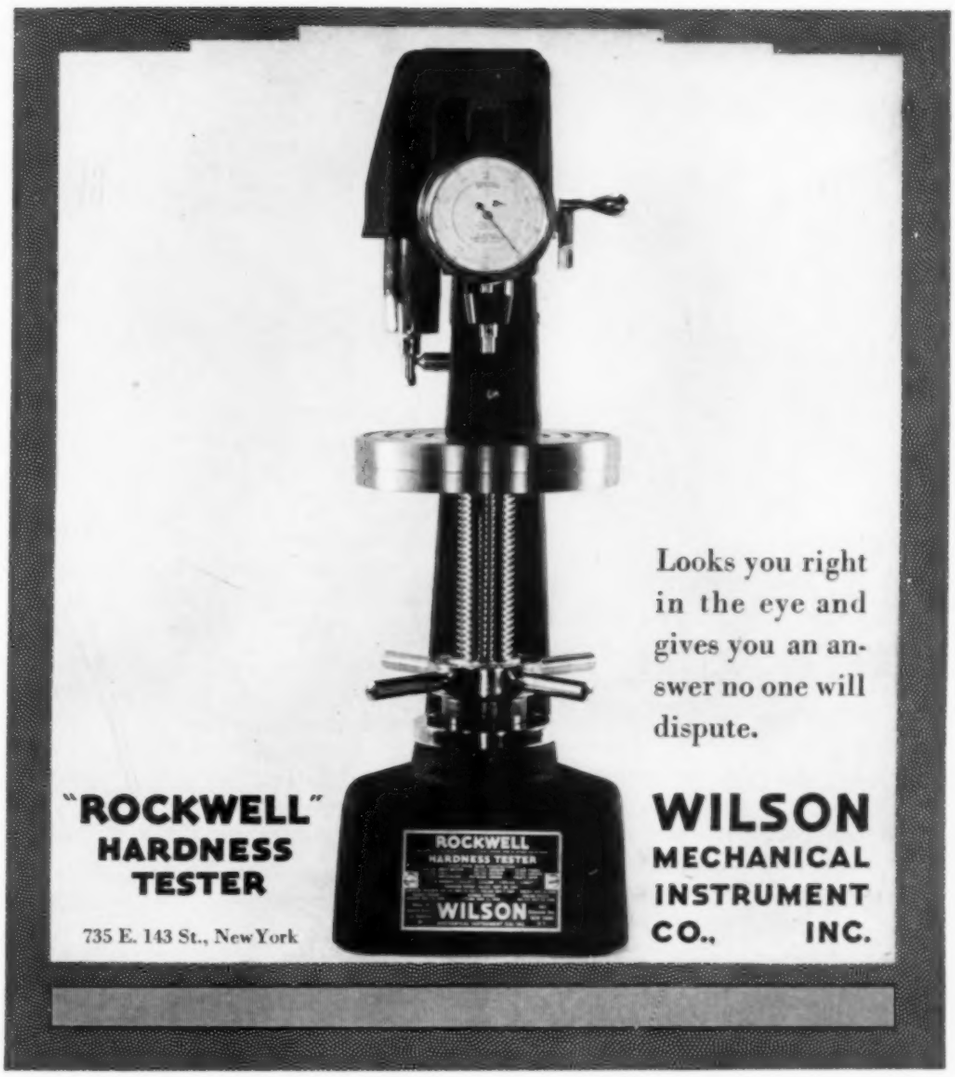
Ship steels

(Starts on page 582) copper is replaced by nickel, the manganese and silicon increased slightly, and 0.20% molybdenum added. This steel has an Izod impact value of 95 ft-lb., a limiting fatigue stress of 60,000 psi., which is reduced to 26,000 by a ⅜-in. Whitworth groove in the position of maximum stress, thus giving a "notch sensitivity" of 0.56, fairly high for the special steels. This material is of interest for such uses as staybolts.

Plain chromium steels, 1% and 3%, are other new steels I regard as of great importance. One variety of the former has 0.45% carbon, 0.65% manganese, 0.50% max. silicon, 1.0 to 1.2% chromium and 0.60% molybdenum. Oil quenched from 1550° F. and tempered at 1225° F., its tensile properties are 160,000; 150,000; 20% in 2 in.; 60%; and Izod impact value of 55 ft-lb. It has good creep strength and is very suitable for bolts for superheated steam lines. In this connection it is immune to brittleness developed after 20,000 hr. service at 750 to 780° F. (Izod figures fall sharply for most strong steels under these conditions.)

Superheater tubes of quite superior quality are made of a low carbon variety (0.10%) of the 1% chromium steel with other elements on the low side of the normal range; they are economical in price, have a limiting creep stress of 15,000 psi. for 1% in 100,000 hr. at 1000° F., and a safe working stress of 8000 psi. — all these figures being better than for tubing made of the 4 to 6% chromium plus molybdenum steel.

The steels containing approximately 3% chromium and 0.5% molybdenum with suitable carbon content have remarkable combinations of properties and are of great utility. With carbon about 0.20% and grain size 8, 3-in. sections oil quenched from 1650° F. and tempered at 1250° F. will harden to the center, giving the following tensile properties at center: 120,000; 100,000; 23.5 in 2 in.; 70; 88 ft-lb. Izod impact; and notch sensitivity in fatigue testing of 0.50. This steel with somewhat lower carbon is excellent for casehardening; its core properties are equivalent to the best and its casehardness is the highest we have been able to obtain in any steel — 940 Vickers pyramid hardness after double quench. It also nitrides readily to a hardness which is adequate for most purposes, and has no spalling tendency.



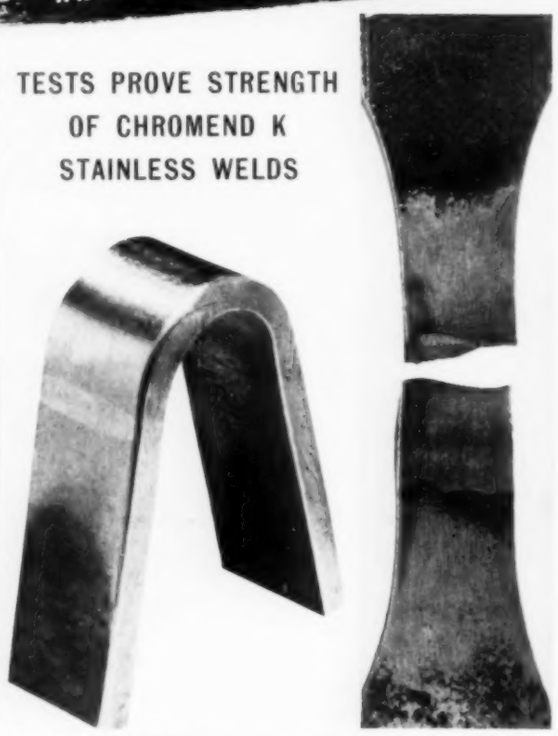
If you buy a hardness tester that is incapable of genuine accuracy of measurement you will be more unhappy than a man in tight shoes.

"ROCKWELL" Testers are made only by WILSON

TESTED

ARCOS ALLOY WELD METAL

TESTS PROVE STRENGTH OF CHROMEND K STAINLESS WELDS



STRENGTH AND DUCTILITY

ARCOS CHROMEND K ELECTRODE

Bend Test ($\frac{3}{8}$" x 1$\frac{1}{2}$")		Tensile Test ($\frac{3}{8}$" x 1" Bar Joint)	
Plate:	19/9 Alloy	T. S.:	85220 p. s. i.
Mandrel:	1$\frac{1}{2}$" dia.	Y. P.:	49460 p. s. i.
Bend:	180°	El. (1")	54.6%
No Cracks		Red. Area:	29.1%

Arcos Technical Bulletins are recognized sources of information on stainless and special alloy welding. Write today for your copy of the just issued 24-page illustrated Technical Bulletin No. 3.

"QUALITY WELD METAL EASILY DEPOSITED"

STAINLESS ELECTRODES

ARCOS CORPORATION

DEPT. A 401 NORTH BROAD ST., PHILA., PA.

PIONEER OF STAINLESS STEEL ELECTRODES IN U. S.

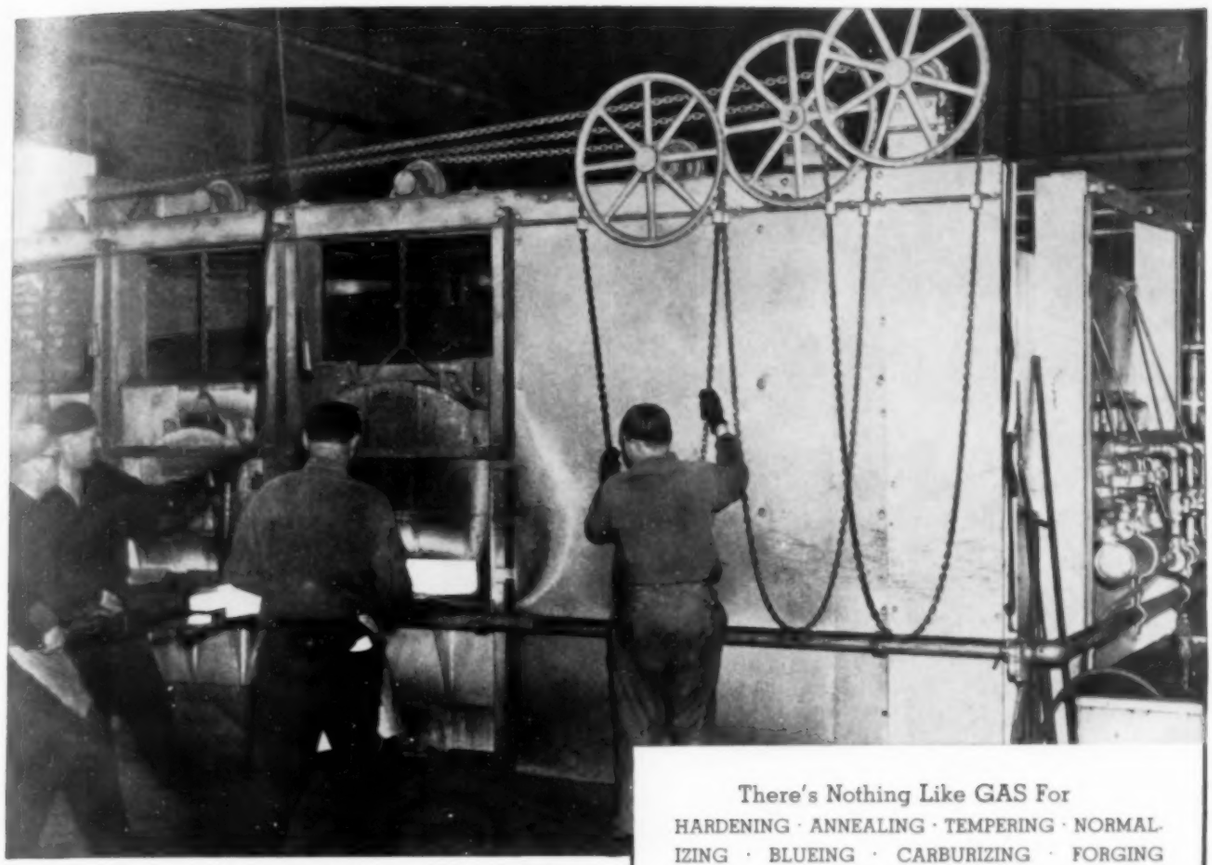
Malleable iron

(Continued from page 562) heating was found to produce many small temper carbon spots close together but fast heating caused large, widely separated carbon spots. The small temper carbon is preferred because with this type of structure carbide elimination is much more rapid. The 'B' iron is a type not previously reported in the literature. It develops small temper carbon spots even when heated rapidly to 1700° F. and since it is not sensitive to rate of heating to 1700° F. in the annealing operation, it is preferred for production purposes. One might expect that two irons that showed so much difference in response to annealing would show different solidification characteristics but the mottling tendency is about the same in both irons.

If we were to analyze completely the influence of all the elements we would find that not only would there be a considerable variation in their stabilizing power but that stabilizing power during solidification would not necessarily be associated with stabilizing power during annealing, nor would graphitizing power of an element during solidification necessarily signify a similar power during annealing. A classification of the possible kinds of influence exerted by various elements during solidification and annealing might be something like this:

Class	Carbide Retaining Power During Solidification	Carbide Stabilizing Power During Annealing	Example
1	Negative (strongly graphitizing)	Negative (strongly graphitizing)	C, Si, Cu and other graphitizers
2	Negative (graphitizing)	Weak	Oxygen added as Fe_2O_3, FeO
3	Weak	Weak	Manganese
4	Weak	Strong	Chromium
5	Strong	Strong	....
6	Strong	Weak	....
7	Strong	Neutral	Moisture

The mechanism by which these various results are obtained, whether by direct influence upon the iron carbide by combination with it or by indirect effect by restricting its freedom of action, is a subject for future detailed investigations. For those who have the necessary training and interest, these problems will provide as fascinating an investigation as can be found in any of the sciences.



Insulated Steel Cased Ingot and Billet Heating Furnace at Columbia Tool Steel Company, Chicago Heights, Illinois. A special feature of this furnace is that it can easily be jacked up on rollers and moved to a new location if desired.

There's Nothing Like GAS For
HARDENING · ANNEALING · TEMPERING · NORMALIZING · BLUEING · CARBURIZING · FORGING
GALVANIZING · CORE BAKING · MALLEABLEIZING
NITRIDING and many other Industrial Processes

"DECIDED REDUCTION
in scale and surface decarburization with
GAS-FIRED BILLET HEATING FURNACE"

Added improvement in material processed; longer furnace life, and reduced repairs to refractories; a decided reduction in scale and surface decarburization, and therefore a greater net return per pound of material processed—these are money-saving, profit-making advantages which the Columbia Tool Steel Company attributes to the new, insulated, steel cased, ingot and billet heating gas furnace shown above.

Modern gas fired equipment for all heat treating purposes gives you these, and other important advantages, because GAS is quick heating, clean, flexible, accurately controllable both as to temperature and furnace atmosphere, and, of all fuels, highest in utilization value.

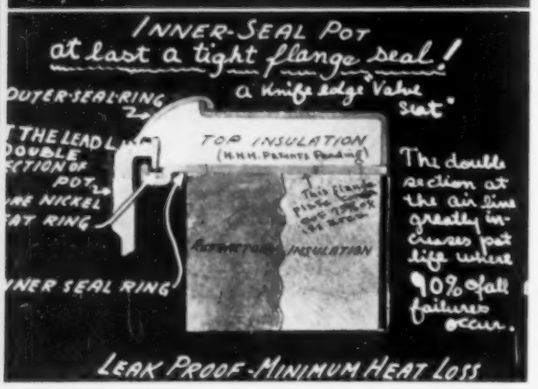
Investigate what GAS can do in your plant.

AMERICAN GAS ASSOCIATION
INDUSTRIAL GAS SECTION
420 LEXINGTON AVE., NEW YORK

Seeing is Believing!

Splined Coupling as used on the "SMOOTH SCREW"
Hot Roller Bearings fully Tested and all data available at temperatures to 2000°F and speeds to
"CATERPILLAR" BEARINGS
A REAL LOAD CARRIER
CATERPILLAR RAIL
Roller Bearing Roller Rail with individual vertical adjustment

UNNEL RAIL"
S ALSO made on a Roller
ail for Heavy Loads
"TUNNEL RAIL" with "I-O Link" In-A-Rail Chain
Runs on top of a rail—returns in the same rail. The simplest and best light load conveyor.


INNER-SEAL POT
at last a tight flange seal!
a knife edge Valve seat.
OUTER-SEAL-RING
TOP INSULATION
(H.H.H. Patents Pend.)
The double section at the air line greatly increases pot life when 90% of all failures occur.
INNER SEAL RING
LEAK PROOF - MINIMUM HEAT LOSS

NATIONAL METALS EXPOSITION

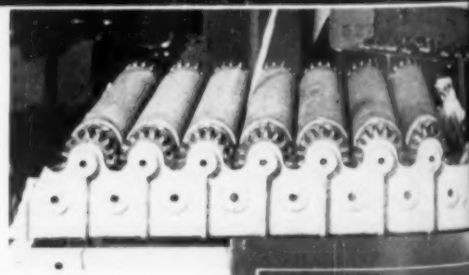
General Alloys Largest Alloy Castings Exhibitor for 19th Consecutive Year

THERE are some who regard advertising as "Ballyhoo", are inclined to discount claims such as our statement in October Metal Progress that we would show more new stuff in our line, and in Furnace Mechanism at this show than all others combined — *times four.*

WE believe you'll agree that such a claim, if true, is of definite interest to you. Not, of course, because you are particularly interested in competitive status in this industry, but because you are interested in *authentic technical progress*, PROGRESS THAT MEANS REDUCED COSTS, BETTER SERVICE to users of Industrial Furnaces, Heat Treating Containers, and Heat & Corrosion Resistant Castings.

I AM proud that new products and mechanisms made under twenty-three patents recently allowed to me were approved by outstanding authorities, but proudest of all of the words of a famous Engineer, who, viewing our exhibit remarked *"Having looked over General Alloys exhibit, I consider that your advertising claims are an understatement of fact".*

H. H. H.



"TRAIN-O-ROLLS"

A Roller Hearth Furnace Mechanism Entirely Within the Furnace running on Hot Roller Bearings. Roll Widths Reduced 50% — no holes through furnace wall — permits true atmosphere control — maximum economy.

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

Flexi-Speed Carburizing Machine

ERAL CYCLES SIMULTANEOUSLY IN ONE FURNACE.
SELF EMPTYING. (H. H. H. PATS. PENDING)

DEVELOPED to utilize the outstanding advances in "individual pot" carburizing practice made by Timken Detroit Axle Company and others, the *"Flexi-Speed" carburizing machine* is offered as a safe middle course between batch box carburizing and continuous gas carburizing, offering flexibility heretofore unobtainable.

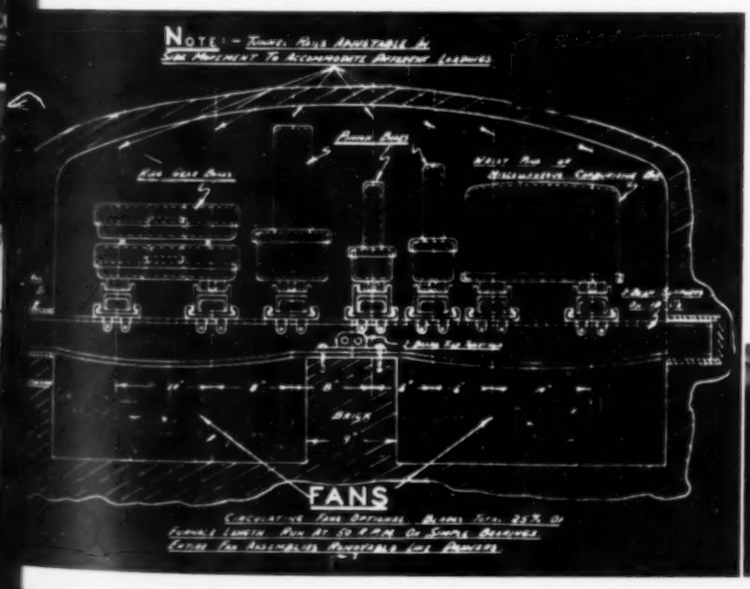
THE "Machine" consists of parallel strands of "I-O-Link" chain, variable as to spacing, which run through a furnace carrying extremely light weight Q-Alloy contoured carburizing containers, (of ⅛" wall section and under) in which production parts are packed in new fine grain high speed carburizing compound.

SMALL containers run on a single strand of chain, while larger ones bridge two strands. Each chain, or pair of chains, can be run independently of the others at any desired speed—THUS MAKING POSSIBLE SEVERAL DIFFERENT TIME CYCLES AND DEPTHS OF CASE, SIMULTANEOUSLY IN THE SAME FURNACE.

BECAUSE the chain is driven from the discharge end, the entering end is lightly loaded (exact reverse of pusher furnaces) and initial temperature can be increased to further reduce time.

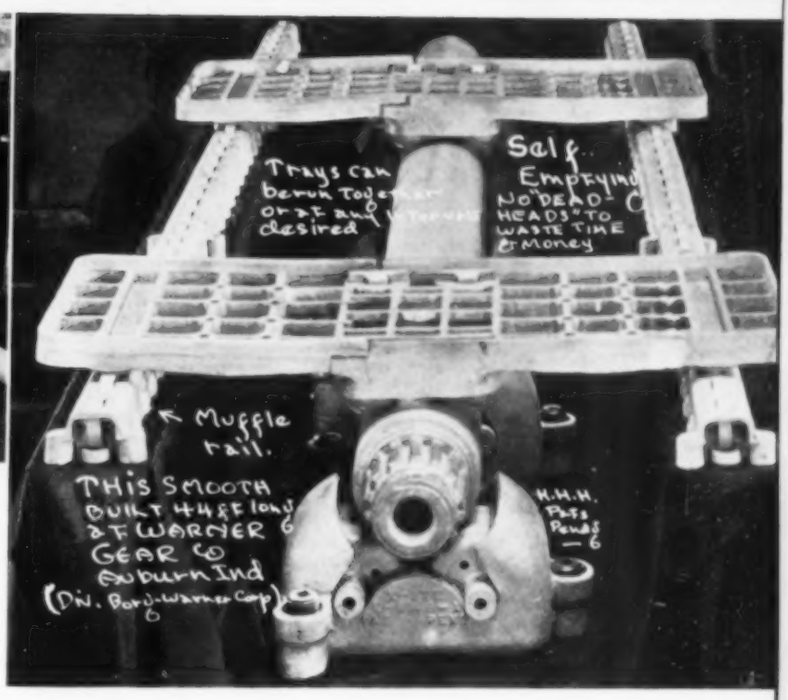
A 12-hour time cycle in batch box packing is reduced to 7 hours. Compound is reduced 80%.

QUALITY of case is improved and 100% uniform-warpage eliminated. One operator loads and quenches. Offers absolute repetitive control of case—can be run *any percentage of capacity, any cycle, any time.* (Small quantities of special parts can be run in tin cans). Flexi-speed carburizing machine can be built into an old or new furnace by any competent furnace builder and is 100% guaranteed by General Alloys.



Smooth-Screw Furnace Conveyor

CARRIES TRAYS WITHOUT COMPRESSION. SELF EMPTYING—CONTINUOUS OR INTERMITTENT

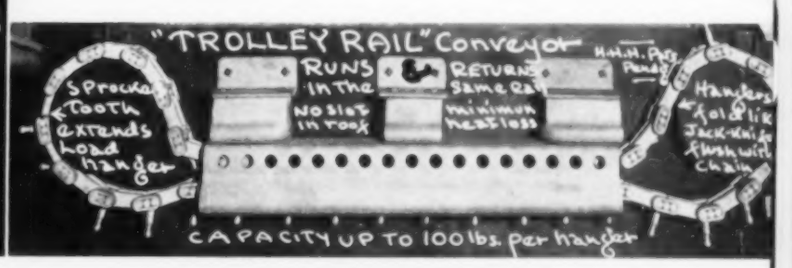

Trays can be run together or at any desired
Self Emptying
NO "DEAD" HEADS TO WASTE TIME & Money
Muffle rail.
THIS SMOOTH BUILT 44&F for BORG & WARNER GEAR CO Auburn Ind
(Div. Borg-Warner Corp)
H.H.H. Pats Pend'g

THE Smooth-Screw tray conveyor offers such outstanding economies that *no person buying or selling any tray furnace can justifiably ignore it.* Pusher furnaces are highly inflexible—grossly extravagant—as compared to *Smooth-Screw.* In slack periods they are a liability, as they must be run *full of trays* to work, using dummy loads if no charge is available. They are not self emptying. AS A FULL DUMMY LOAD MUST BE PUSHED IN TO GET THE CHARGE OUT, AND THIS DUMMY LOAD MUST BE BROUGHT TO HEAT AND PUSHED OUT TO GET A NEW CHARGE IN—*A COSTLY, WASTEFUL PROCEDURE.*

SMOOTH-SCREW moves trays without compression (does not use costly alloy trays as a "ramrod"), one or a full load, intermittently or continuously, at any speed desired—self emptying. (The "Smooth-Screw" illustrated is installed in a 44 ft. furnace at Warner Automotive Parts Division of Borg-Warner Corporation). *Trolley Rail* conveyor can be installed in the roof of any furnace to carry suspensible loads like gears, baskets of small parts, enameled ware, etc., most economically.

CONSULT your furnace builder for G. A. Mechanism (all covered by H. H. H. patents issued or pending).

NOTE—Items shown are a small fraction of GA's *new stuff.*


"TROLLEY RAIL" Conveyor
RUNS IN THE
RETURNS SAME RAIL
NO SLOT IN ROOF
MINIMUM HEAT LOSS
H.H.H. Pats Pend'g
Sprocket Tooth extends load hanger
Hangers "Solalik" Jack-chain flush with Chain
CAPACITY UP TO 100 lbs. per hanger

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OLDEST AND LARGEST EXCLUSIVE MANUFACTURER OF HEAT & CORROSION RESISTANT ALLOYS

Notes about contributors

Senior author **Edwin C. Wright** of the article on failures of refinery still tubes (page 573) is chief metallurgist of large and well-known National Tube Co., and makes his headquarters at the general offices in Pittsburgh. A graduate of University of Michigan in chemical engineering and of University of Pittsburgh in metallurgical engineering, Wright spent three years in the Army, followed by two years in the Ford Motor Co. and five years as associate professor of metallurgy at University of Alabama. In 1926 he left the teaching profession to join National Tube Co. as metallurgist, and has been with that organization ever since.

H. Habart has also been with National Tube since 1926, when he came there a graduate of University of Alabama with a M.S. degree. (His B.S. in metallurgy came from Case School of Applied Science in 1925.) Habart is metallurgist at the Ellwood Works.

Recognition of the value of **A. L. Boegehold's** technical experience and knowledge is reflected in his membership on the ASM Publication Committee and various Handbook committees, his membership on the Advisory Committee and several subcommittees of the American Foundrymen's Association, and vice-chairmanship of the Committee on Alloy Cast Iron. Further recognition and honor came to him when he was selected to deliver the Campbell Memorial Lecture at the Annual Meeting of the ASM last month at the National Metal Congress. His lecture is briefly summarized, beginning on page 557 of this issue. Boegehold graduated from Cornell in 1915 with a degree in mechanical engineering, and began his industrial career as mechanical engineer, Remington Arms & Ammunition Co., Bridgeport, Conn. He served in various capacities with Bridgeport Brass Co., Army Ordnance Department at the Bureau of Standards, and Remington U.M.C. Co. until 1920 when he became associated with General Motors Research Corp. in Dayton, Ohio. Later he was transferred to Detroit, and since 1925 has held his present position as head of the Metallurgy Department, Research Laboratories, General Motors Corp. He is also a member of the A.I.M.E. and chairman of the Detroit Chapter ASM.

Starting in the East after graduating in metallurgy from Sheffield Scientific School, Yale University, **E. K. Smith's** career has taken him to various parts of the country before winding up again in the East as service metallurgist for Electro Metallurgical Co. In sequence he has been chemist for Eastern Malleable Iron Co., Naugatuck, Conn., metallurgist and later superintendent for Wisconsin Malleable Iron Co., Milwaukee, and metallurgical engineer, Stockham Pipe Fittings Co., Birmingham, Ala. Such experience, so closely confined to the field of cast iron, has given him a well-founded basis for his paper on "Chromium Steel and Iron Castings" presented at the Western Metal Congress last March. A part of this forms the basis of an article telling new things about "Chromium Cast Irons", starting on page 563.

E. K. Smith

A. L. Boegehold

H. Habart

Edwin C. Wright